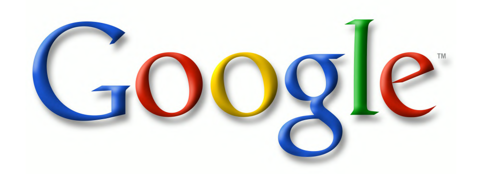
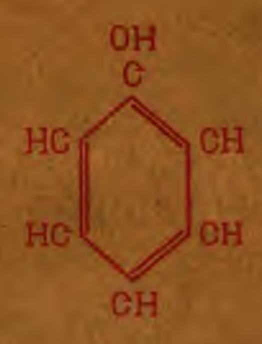


# Carbolic Acid and Its Production from Benzol




With Illustrations of Apparatus

BY

GEORGE H. STEVENS



# The Manufacture of Synthetic Phenol from Benzol by Sulphonation

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Synthetic Phenol (Carbolic Acid), its uses, the raw materials, and the necessary Apparatus and Equipment for its production on a commercial basis

BY

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January 1916

## CARBOLIC ACID, HYDROXY-BENZENE, PHENIC ACID.

## BENZO-PHENOL, PHENOL, $C_6H_5OH$.

These are the several designations that are given to this product, which was discovered by Runge in 1834 (Pogg. Ann., XXI 69, XXX 308), who called it Carbon Oil Acid, or Carbolic Acid.

Phenol is the type of a whole class of bodies which stand, as it were, midway between Alcohols and Acids.

The Phenols form a class by themselves, and are those Aromatic compounds in which the Hydrogen atoms of Benzene nuclei are replaced by Hydroxyl (O H). The Hydrogen of the latter is easily replaced by Metals or Alcoholic Radicals, but the other characteristics of a real acid are absent.

Carbolic Acid is generally obtained from Coal Tar, and principally from the Carbolic oil fraction 210° to 240° or 250° C. This fraction is treated with Caustic Alkalies, in which the Phenol dissolves. The alkaline solution is then decomposed by the addition of a mineral acid and the Phenol is released.

Phenol is also obtained from the light oils (110° to 210° C.), but all the Phenol thus recovered from the fractional distillation of Coal Tar contains water, resinous matter, Cresols and other Phenols, and must be repeatedly distilled and refined before it finally becomes a pure product.

Phenol is a colorless, crystalline mass. The crystals when pure are long, colorless prisms. It is hygroscopic, has a characteristic odor, hot, burning and sweet taste, and poisonous and antiseptic properties.

It is volatile with steam. Ferric salts impart a violet color to its neutral solutions, and when Phenol is fused, it is as limpid as water and perfectly colorless.

Phenol is a weak acid (Walker, Phys. Chem., Chap. XXIV), which is shown by Carbonic Acid easily decomposing its Sodium Salt.

The nitration of Phenols furnishes Nitro-Phenols which can be converted into Amido-Phenols by reduction.

Laurent in 1841 obtained it pure and gave it the names Hydrate de Phenyle or Acide Phenique, from a Greek word meaning to illuminate, probably because it occurs in the Tar, produced in the manufacture of illuminating gas.

Gerhardt, who prepared Carbolic Acid from Salicylic Acid, introduced the name Phenol, indicating thereby that it was an Alcohol.

In 1867 Lister showed its great importance in surgery as a disinfectant.

Phenol is highly poisonous, and has a strong caustic action on the skin, quickly causing blisters, it also causes the skin to harden or shrink.

A remedy for the pain and bad effects of Phenol blisters is fatty oil.

Internally its poisonous properties are shown in its corrosive action upon the epithelium and its property of coagulating Albumen. It appears to act on the nervous system by paralyzing the nerve centers.

According to Allen, even a momentary contact of strong acid with an extensive surface of the lower part of the body is mostly fatal, but it has comparatively little effect upon the arms.

When weak solutions of Phenol are applied to the skin, for any length of time, a surface paralysis of the nerves, or numbness, results a few hours afterwards. This exceedingly painful feeling lasts for many hours, and the skin becomes as sensitive as though blistered, and yet may show no trace of irritation whatever.

In a few days time the condition will generally disappear.

The poisonous action of Phenol is given by Bokorny (Chem. Zeit. 1906, 554).

Strong Phenol dissolves Gelatin completely, but coagulates it when added to its aqueous solutions.

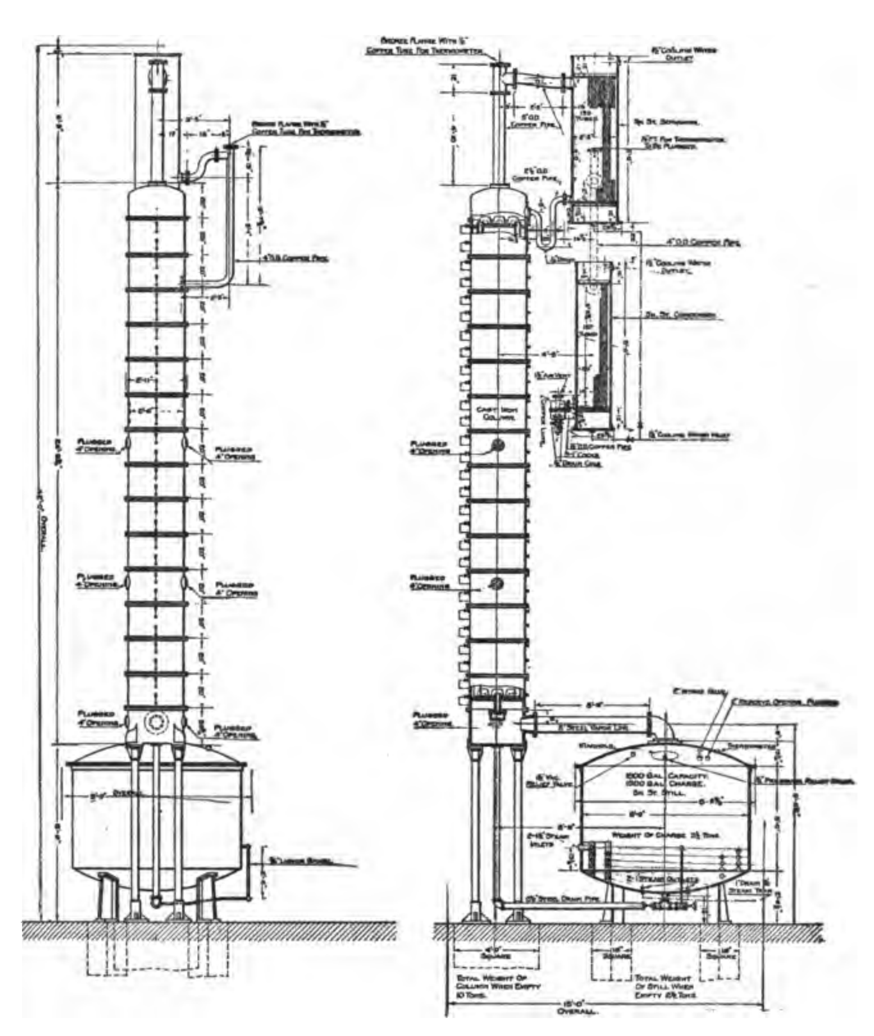
The unpleasant odor of Carbolic Acid can be entirely masked by a little Oil of Geranium.

Phenol forms true salts. An atom of Hydrogen is replaced by an atom of a monovalent metal. (Wahl and Atack, Manufacture of Organic Dyestuffs, 1914).

The Sodium salt is called Sodium Carbolate, Sodium Phenolate, or Sodium Phenate, or Phenoxide.

Most of the salts of Phenol are readily soluble in water, and are far more stable than their corresponding Alcoholates.

Indigo blue (Indigotin) is soluble in hot Phenol and may



CAST IRON BENZOL RECTIFYING COLUMN AND SHEET STEEL STILL, WITH SEPARATOR AND CONDENSER.

28 chambers, 30 in. column, 42 ft. high, weighing 10 tons, and 1,800 gal. sheet steel still, weighing 2½ tons. Can be built for $2,300 to $2,500.00. Capacity 50 gal. Benzol per hour.

be obtained in crystals on cooling the liquid.

Obermiller (Berl. Ber., 1907, 3623) has studied in detail the action of Sulphuric Acid on Phenols.

For the sulfonation of Phenol, see Kekule (Ber., 1869, 2, 330) and Obermiller (Ber., 1908, 41, 696).

Phenol, like the Alcohols, is capable of forming Ethers (Anisole) and Esters (Phenylacetate).

Phenol dissolves in 15 parts of water at 20° C. and very readily in Alcohol, Ether, Glycerin, Carbon Disulphide and Glacial Acetic Acid. At 84° C. Phenol is miscible in all proportions with water. (Green, Organic Coloring Matters, 1908).

The per cent. of water in Carbolic Acid, according to Vulpius (Wagner-Fischers, Jahresber., 1884, 494) can be tested by adding Olive Oil.

Carbolic Acid free from water can be mixed with many volumes of Olive Oil without becoming turbid. The more water the Carbolic contains, the less Olive Oil it will take.

Carbolic Acid containing 10% of water will give a clear solution when mixed with four volumes of Olive Oil, but will become strongly turbid with five volumes.

1% of water in Phenol can be recognized by shaking the Phenol with its own volume of Chloroform or Ether, in which case it will produce a milky liquid.

The quantity of water in Phenol can also be determined by the increase in volume of a concentrated solution of Calcium Chloride.

Phenol containing from 7% of water upwards becomes liquid.

Alexeieff gives a table of solubilities of Phenol in water and water in Phenol.

Adrieenz (Ber., 1873, 443) gives a table of the volumes of Phenol.

Hamberg (Ber., 1871, 751) gives the solubility of Phenol.

Seidell (Solubilities of Inorganic and Organic Substances, 1911) gives tables of solubilities of Phenol in Water, Paraffine, Benzol, Acetone, Aqueous Tartaric Acid, Amyl Alcohol, Aqueous Potassium Sulphate, Toluene, m-Xylene, and Carbon Tetrachloride.

For solubility in water see Alexejew (Wied., Ann., 28, 305, 1886), Schreinemaker (Z. physik. Ch., 33, 79, 1900), Rothmund (Z. physik. Ch., 26, 474, 1898), Vaubel (Jour. fur praktische chemie. Leipzig (2), 52, 73, 1895).

For solubility in Amyl Alcohol see Herz and Fischer (Ber., 37, 4747, 1904).

For solubility in Benzol, Vaubel (Jour. fur praktische chemie. Leipzig (2), 67, 476, 1903), Schweissinger (Pharm. Ztg., 1884, 1885), Rothmund and Wilsmore (Z. fur physikalische Chemie, Leipzig, 40, 623, 1902).

For solubility in Toluene and Xylene, Herz and Fischer (Ber., 38, 1143, 1905).

For solubility in Carbon tetrachloride, Vaubel (Jour. fur praktische chemie. Leipzig (2), 67, 476, 1903).

Schreinmaker gives the solubilities of Phenol in Acetone, and in Tartaric Acid aqueous solutions.

Schweissinger (Pharm. Zeit., 1885, 259) shows the solubility of Phenol in Petroleum-spirit at different temperatures. At 43° C. one volume of the former dissolving in one volume of the latter.

The solubility in Paraffine Oil is about the same.

This property of Phenol is utilized in the manufacture of loose crystals.

The history, manufacture, application and examination of Carbolic Acid are monographically treated by H. Koehler in his Carbolsaure and Carbolsaureparate, Berlin, 1891.

Synthetic Phenol is in every way the same as the regular Phenol, except that it is apt to be the purer product of the two.

There can be no Cresols present in synthetic Phenol.

## MELTING AND BOILING POINTS OF PHENOL.

Lunge (Coal Tar and Ammonia, 1909) gives the melting point as 43° C., boiling point 183° C. and Sp. Gr. 1.084 at 0° C.

Martin (Dyestuff and Coal Tar Products, 1915) states that commercial Phenol should melt at 39° to 40° C. and boil at 183° to 186° C.

Green (Organic Coloring Matters, 1908) gives the melting point as 41° C., boiling point 188° C., Sp. Gr. at 40° C. 1.05433 for pure Phenol, and that the commercial product melts at 30° and boils at 183° C.

Cain and Thorpe (Synthetic Dyestuffs, 1913) give the melting point at 42° C., boiling point 181.5°, and 30° C. as the melting point of commercial samples.

Wahl and Atack (Organic Dyestuffs, 1914) gives the melting point as 42° C. and boiling point 182° C.

Perkin and Kipping (Organic Chemistry, Part II) give the melting point as 42° C. and the boiling point as 183° C.

Richter (Organic Chemistry, 1911, Vol. II) gives the melting point at 43° C., boiling point 183° C. and the Sp. Gr. at 0° as 1.084.

Bernthsen (Organic Chemistry, 1912) gives the melting point as 42° C. and boiling point as 181° C.

Choay (Comptes. rend., CXVIII, 1211) determined the melting point of absolutely pure Phenol as 42.5° C. or 43° C., and the boiling point as 178.5° C., and ordinary "pure" Phenol as fusing at 35.5° C. and boiling at 188° C.

The German Pharmacopoeia requires a fusing point of 40° to 42° C.

The solidifying point is fixed by some authorities at 39° to 41° C.

Eger (Pharm. Zeit., 1903, 210; Chem. Zeit., Rep., 1903, 86) claims that the purest Phenol solidifies at 40.9° C., and its fusing point at most is only 0.1° higher.

In damp air Phenol absorbs water, and its fusing point is lowered by the formation of a hydrate $C_6 H_6 O H_2 O$ containing 16.07% of water and fusing at 17.2° C. (Allen, Analyst, III, 319). The hydrate begins to lose water at 100° C., and thus gradually arrives at the B. P. of anhydrous Phenol.

Phenol fusing at 42° C. is less deliquescent than that melting at 35° C.

Kraemer and Spilker have given a method for determining the solidifying point of Phenol.

It is seen from the foregoing that the authorities vary greatly as to the true melting and boiling points of Phenol. This is due largely to the impurities that are present in the most of the regular Carbolic Acid that has not been made synthetically.

The three Cresols are present to a greater or less extent in the most of commercial Phenol.

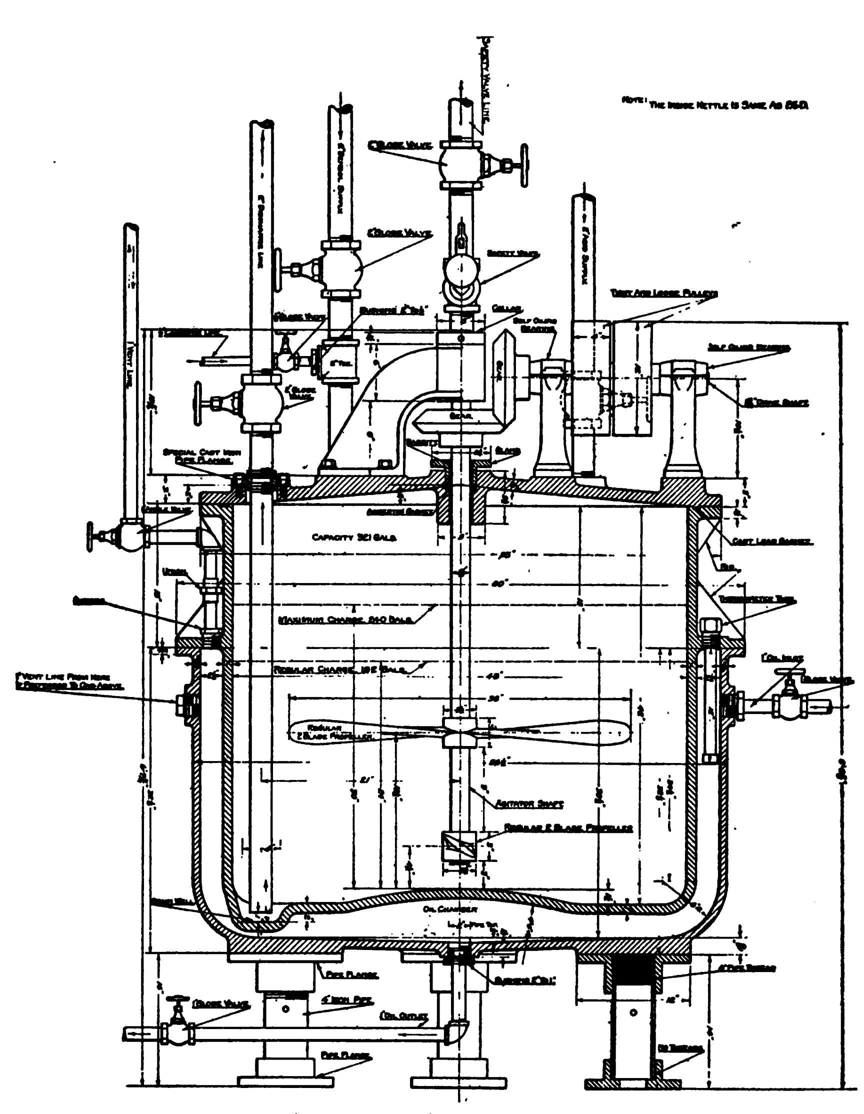
o-Cresol has a melting point of 30° C., boiling point of 191° C. and Sp. Gr. 1.043.

m-Cresol has a melting point of 4° C., boiling point 203° C., and Sp. Gr. 1.035.

p-Cresol has a melting point of 36° C., boiling point 202° C., and Sp. Gr. 1.034.

The melting points of the Cresols are seen to be much below that of Phenol, and their presence then is indicated in the low melting point of commercial Phenol.

The boiling points of the Cresols are much higher than Phenol, again being responsible for the variations in the boiling point of Phenol.



Section-Elevation Of Cast Iron Sulphonating Kettle With Syphon Discharge

## CAST IRON JACKETED SULPHONATING KETTLE, WITH AGITATOR AND SYPHON DISCHARGE.

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**Eight sheets of detail drawings and names of manufacturers who have submitted bids are furnished.**

**The same kettle with 4 way yoke support for agitator drive, same price.**

**Or either style of kettle with valve outlet in bottom, instead of syphon discharge, same price.**

**Price of either set of these drawings, $100.00.**

The Sp. Gr. of the Cresols is also lower than Phenol.

The presence of 1.3% of Cresol in Phenol reduces the M. P. 8° C. or to about 31.5° C., according to some authorities.

The presence of water, even in Crystalline Phenol, materially affects the melting and boiling points. As much as 5% of water may be present in Crystalline Phenol and the fusing point materially lowered in consequence.

## LITERATURE.

There is considerable literature on Carbolic Acid in general, and especially on its manufacture from Coal Tar distillates. Most of this work has been reviewed, covered and exhaustively treated on, in Lunge's Coal Tar and Ammonia, Part II, 1909.

The literature on synthetic Phenol, however, is more limited and frequently confined to only a few lines or paragraphs, in the most of the descriptions. Some of the accounts are found in the following, which are the sulfonation process.

Wurtz, Dusart and Kekule, in 1867, discovered simultaneously, that on fusing Benzene-monosulphonic Acid with Caustic Potash, that Potassium Phenate and Sulphite are produced; upon decomposing the Phenate, Phenol results.

Caustic Potash being higher priced, Caustic Soda is used instead.

G. Schultz, Die chemie des Steinkohlentiers, 1900, Vol. I, 139.

Allen (Com. Org. Anal., Vol. III, 1910, 289), giving two methods for the synthesis of Phenol.

Cain and Thorpe, Synthetic Dyestuffs, 1913.

Fay, Coal Tar Dyes, 1911.

Perkin and Kipping, Organic Chemistry, Part II.

Bernthsen, Organic Chemistry, 1912.

Jayne, Am. Jour. Pharm., Dec., 1891, and J. S. C. I., 1892, 264.

Wahl and Atack, Organic Dyestuffs, 1914.

Georgievics, Chemistry of Dyestuffs, 1903.

Blucher, Modern Industrial Chemistry.

Richter, Organic Chemistry, 1911, Vol. II.

Lunge, Coal Tar and Ammonia, 1909, Part II.

Phenol can be produced artificially from Benzene, by oxidation with nascent Oxygen, or even with free Oxygen (Friedel and Craffts, Bull. Soc. Chim., XXXI, 463).

An account of the synthesis of Phenol from Acetylene is given by Berthelot (Compt. rend., 1898, (23), 908-911), and abstracted (J. S. C. I., 1898, 127), and also (Annalen, 154, 132), (G. Schroeter, Annalen, 303, (1), 114-132).

Phenol is also obtained by the oxidation of Aniline. The process being as follows:

Pure Aniline Oil, preferably that grade called "Aniline for blue," is dissolved in water in a lead lined tank, covered with a hood and provided with stirrers and leaden steam coils.

The solution is acidified very strongly with Sulphuric acid, and to the hot liquid a solution of commercial Sodium Nitrite is gradually added, when Phenol is at once formed.

In this reaction the Sodium Nitrite in contact with the acid solution, liberates Nitrous acid, which forms Diazobenzene Sulphate with the Aniline Sulphate.

$$2(C_6 H_5 N H_2) + H_2 S O_4 + 2(H N O_2) = 2(C_6 H_5 N_2) S O_4 + 4(H_2O)$$

but as the solution is hot, the Diazo compound at once decomposes with the formation of Phenol, and evolution of Nitrogen.

$$2(C_6 H_5 N_2) S O_4 + 2(H_2 O) = 2(C_6 H_5 O H) + H_2 S O_4 + 4 N$$

The only practical and economical way, however, is by the Sulphonation process, starting with Benzol.

## USES.

Phenol is used in the manufacture of Picric Acid.

Schmidt & Glutz (Mon. Sci., 1878, 1115; Ber., 2, 52), (French Pat., 345,441).

Laurent (Ann., 1843, 43, 208).

(Eng. Pat., 4539, 1889), (French Pat., 315,695).

(Martins., Ind. Chem., Vol. I, p. 632), Fay (Coal Tar Dyes, 1911).

Phenol is used in producing Coralline or Aurine.

Zulkowski (M. f. Ch., 1895, 358-403), Runge (Berz. Jahresber., 15, 423), Schultz (Die Chemie des Steinkohlentheers, 2nd Edit., II, 515).

Phenol is used in Azo colors, in Oxidised Triphenylmethane colors, and in the Salicylates. It is used as a disinfectant, for

antiseptic purposes, as a preservative of beet juice (Cunisset Bull. Soc. Chim., 1874, XXI, 47) and (Hulwa, Wagners Jahresber., 1875, 795), and for destroying Lactic Acid ferment in the manufacture of Alcohol (Maercker, Wagners Jahresber., 1872, 826).

Kellner (Chem. Zeit., 1884, 122) found it a good remedy for the parasitic diseases of plants and animals, and manure containing 2% of it is harmless to the plants, except when put on the field with their seeds.

Kletzinsky (Wagners Jahresber., 1864, 601) showed that it possessed tanning properties, and Baudet (Wagners Jahresber., 1870, 669) obtained a patent for the same purpose.

Harcke (Ger. Pats., 16,022 and 19,633) adds Phenol in the currying process, and produces artificial leather with Phenol as one of the ingredients.

Shaw (Ger. Pat., 27,270), and Beda (British Pat., 16,647, 1886) proceed in the same manner.

Sodium Phenolate prevents dry rot in timber, and is also used in the manufacture of lining stones for converters (Hustener Gewerkschaft, Z. angew. Chem., 1889, 132).

The Neue Augsburger Kattunfabrik (Ger. Pat., 95,692) employs a weak solution of Phenol in calico printing.

Gassmann and the Usines du Rhone (Ger. Pat., 99,756) employ Phenol for dissolving coloring matters insoluble in water.

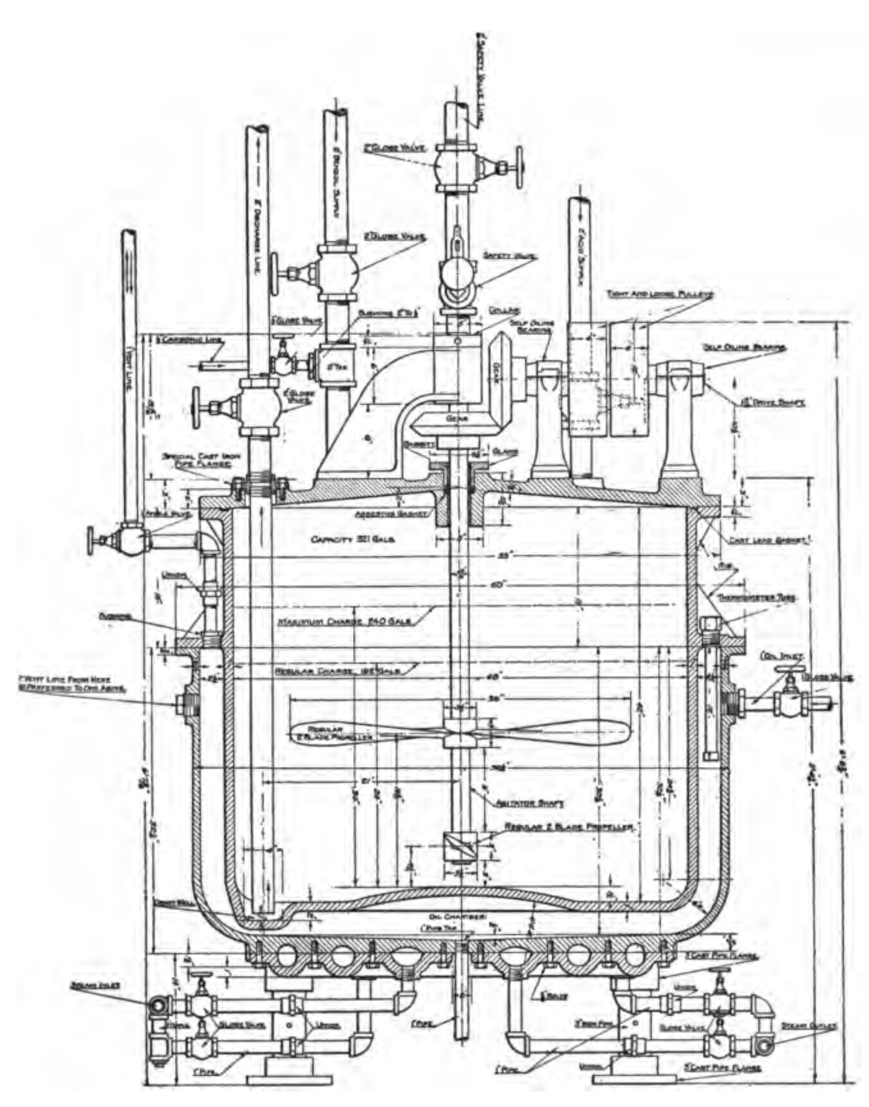
Justin Mueller (Bull. Soc. Ind., Mulhous, Vol. 76, p. 72) finds that an addition of Phenol to the colors for printing on wool has the same effect as chlorinating the wool.

Phenol is a solvent for Casein, and numerous patents have been taken out by B. B. Goldsmith covering its application in thermo-plastics.

Phenol and Formaldehyde are the principal constituents of the Phenol-Aldehyde condensation products, or synthetic resins, now so generally used and designated as Bakelite and Condensite. The latter is the important constituent of the Edison Disk Talking Machine Records. Numerous patents cover the many variations in these synthetic Resins and the Varnishes and Lacquers made from them. (See A. Luft, L. H. Baekeland, H. Lebach, J. W. Aylesworth, De Laire, Wetter, Knoll & Co., Blumer, Bayer, Kleeberg, Smith and Story). See Balkeland (J. S. C. I. (3), 1909; (8), 1909; (12), 1911; (10), 1912; (6), 1913 (2), 1916: Trans. Am. Electrochemical Soc. 1909, 593).

Phenol is combined with soap, and one of its common designations is Creoline.

Lysol is a water soluble preparation of Phenol, another



Section - Elevation Of Cast Iron Sulfonating Kettle With Syphon Discharge

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**The same kettle with 4 way yoke support for agitator drive, same price.**

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**Price of either set of these drawings, $100.00.**

designation for it is Sapocarbol.

Anthrasol is a preparation of Tar-Oils containing Phenol, and used for therapeutic purposes.

Lysoform is Lysol and Formaldehyde.

Lysosulfol is a Sulphur compound of Lysol.

Carbollysoform is Lysoform and crude Carbolic Acid.

Non-poisonous disinfectants called Oxychinaseptol or Diaphtherin are made from Phenol and Oxyquinoline.

Solveol for surgical purposes is Sodium Salicylate and Cresol.

The Sozoiodols of Trommsdorf unite the action of Iodoform with that of Carbolic Acid in the treatment of wounds.

Phenosalyl is a mixture of Carbolic Acid, Salicylic Acid, Lactic Acid, Menthol, Glycerin and Borax.

Microsol is a solution of Cupric Sulphate containing free Sulphuric Acid and 10% Cupric Phenolsulphonate.

Sanatolyse consists of Carbolic Acid, Sulphuric Acid and Ferrous Sulphate.

Metakalin in the form of tablets contain Phenol (B. P. 9953, 1904).

Sozal (Scherges, Pharm. Zeit., 1892, 489) is Aluminum paraphenosulphonate and more efficacious than Aluminum Acetate in the treatment of ulcers.

Salol is Salicylic Acid fused with Phenol and then heated with Phosphorus Oxychloride (Neucki), it is Phenylate of Salicylic Acid.

Aspirin is Acetylsalicylic Acid and is made by heating Salicylic Acid with Acetic Anhydride, or Acetyl Chloride, and recrystallizing from Chloroform. (U. S. Pat., 749,980), (Eng. Pat., 15,517, 1902.)

Phenol-Zinc solutions are used in preserving timbers from decay and dry rot (Chem. Zeit., 1885, 602).

Phenol yields Phenol Carboxylic Acid with Carbon Tetrachloride and Sodium Hydroxide.

Phenol Aldehydes are produced from Phenol, Chloroform and Caustic Soda (Salicylaldehyde).

Phenol condenses with Formaldehyde to Phenol Alcohols (Seligenine).

Heating Phenol with Malic Acid and Sulphuric Acid produces Coumarine.

Dyestuffs belonging to the Aurine series are obtained from Phenol and Benzotrichloride.

Hydrogen Dioxide converts Phenol into Catechol, Hydroquinone and Quinone.

By the action of Fused Sodium Hydroxide on Phenol, Phloro-

glucinol, Catechol and Resorcinol are formed with other products.

A liquid Phenol soap of 12% strength is made by mixing Carbolic Acid, Caustic Potash, Oleic Acid and water (Chem. Ind., 1897, 346).

Helmers makes Phenol soluble by means of the Sulphonic Acid of mineral or Resin Oil (Ger. Pats., 76,133 and 80,260).

Ortho-Oxyquinoline is employed by Fritzsche (Ger. Pat., 88,520) in dissolving Phenol in all proportions in water.

Alb. Friedlander (Ger. Pat., 181,288) makes Phenol soluble in water by adding small quantities of Sulphonic Acids or Sulphonates.

Hiscott (B. P. 20,246, 1896) mixes 50 to 100 parts commercial Carbolic Acid with half its weight of melted Resin, sufficient concentrated Caustic Soda solution, and 7 to 8 parts of Cotton-seed or Cocoanut Oil, to make the Phenol soluble.

Jeyes (B. P. 16,427, 1885) saponifies Carbolic Acid and Cocoanut oil, by Caustic Soda, and makes the product more soluble by adding Sodium Sulphate, or Carbonate, during the fusion.

Hargreaves (B. P. 18,469, 1889) employs the Chlorinated Phenols or their salts for the same purpose.

Carbolic Acid soap is sold to contain from 10 to 20% of Phenol, but usually contains much less and loses a part by evaporation (Allen's Org. Anal.).

Solutions of Phenol in oil do not possess the same disinfecting power as those in water (Koch. Wolffhugel and Knorre, J. S. C. I., 1882, 244).

Disinfectant powders made from Phenol and Calcium Sulphite, China Clay, Lime and other materials are now numerous.

Carbolic Acid tablets for deodorizing the air in closets, hospitals, etc., are in popular use.

Phenolith is anhydrous Boric Acid and Phenol. (Holtz, Ger. Pat., 6498), (Lutze, British Pat., 22,136, 1897).

Phenol and Oxalic Acid are mixed by Rutgers (Ger. Pats., 137,584 and 141,421).

Dawson (British Pat., 11,908, 1895) gelatinizes Phenol by adding waxes.

England (British Pat., 16,422, 1894) makes antiseptic manure of Phenol, Superphosphates and Gypsum.

Lysopast and Phenopast are mixtures of Lysol and Phenol.

Raetz (British Pat., 27,889, 1903) renders solutions of Phenols solid, by treating them with Aldehydes and Ketones.

Phenolphthalein is made from Phthalic Anhydride and Phenol (Ber., 1871, 4, 658), (Ber., 1876, 9, 1230), (Ann., 1880, 202,

68).

Diphenylene Oxide is produced when Phenol is distilled over Lead Oxide.

Aurine results when Phenol is heated with Oxalic or Formic Acid and dehydrating agents.

Potassium Permanganate oxidizes Phenol to inactive or Mesotartaric Acid.

Chlorine changes Phenol to Keto-chlorides.

Chlorine and Caustic Soda convert Phenol into Trichlor-R-pentene dioxycarboxylic Acid.

Anisole is obtained by heating Phenol and Caustic Potash with Ethyl or Methyl Iodine in Alcohol solution.

Alkali salts of Phenol are converted by Carbon Dioxide, at higher temperatures, into the Alkali salts or Oxy-acids, Phenol-Carboxylic Acids (Salicylic Acid).

Salicylic Acid is produced by passing heated Carbon Dioxide over Sodium Phenolate (Kolbe). It is used largely in medicine and chiefly in the form of its Sodium salt, and as a component in the production of mordant Azo-dyes.

The suphonation of Phenol furnishes Phenol-sulphonic Acids, which find their use in the manufacture of dyestuffs and medicine. (Sozolic Acid and Aseptol) their salts are sometimes sold as Sozoidols.

Of all the above technical uses, probably the commonest are for disinfectants, Salicylic Acid, and for synthetic Resins.

The foregoing are not by any means the only uses of Phenol, but they serve to show that Phenol, or Carbolic Acid, has an extensive use in the technical arts and for pharmaceutical purposes, aside from its frequent use in the production of Picric Acid or Trinitro Phenol, which appears as Melinite, Roburite, Shimosite and Lyddite, the high explosives of modern warfare.

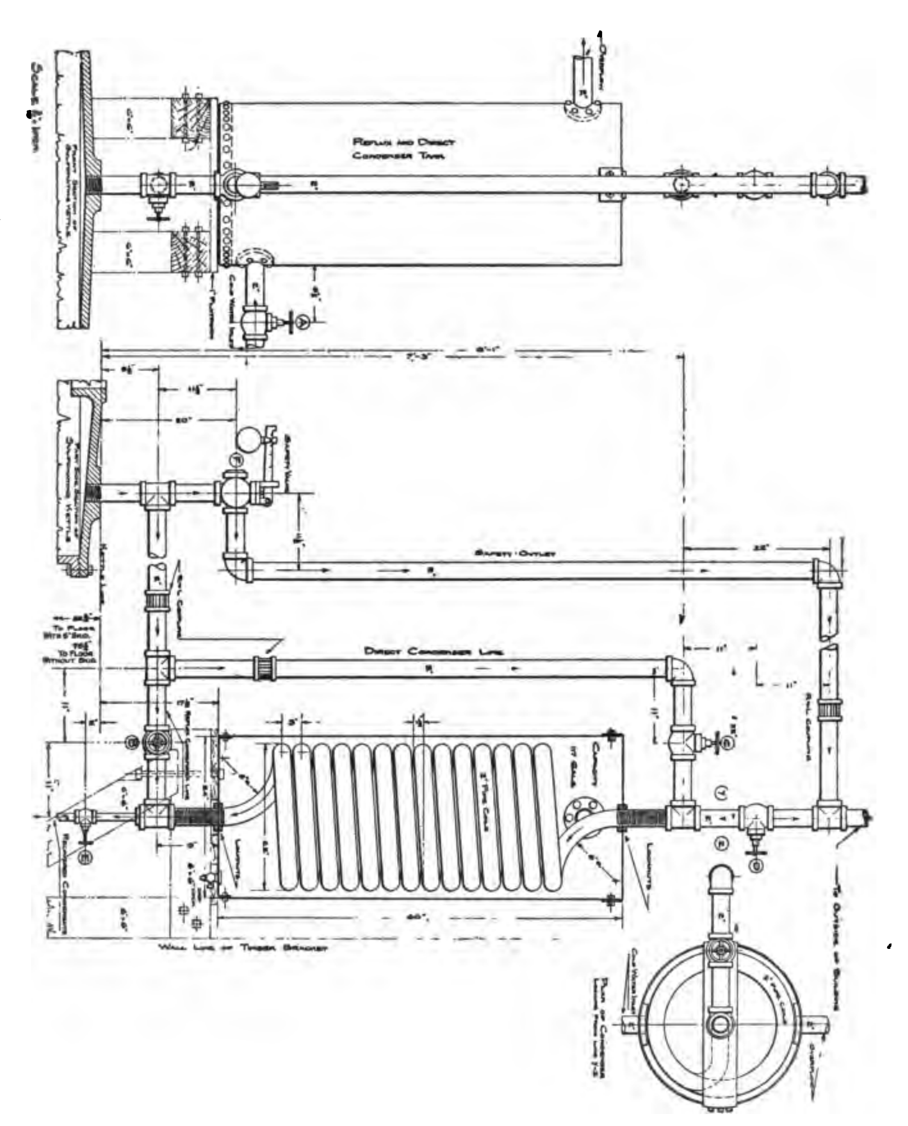
## THE REDDENING OF PHENOL.

The reddening of Phenol is attributed to many different causes.

Kohn & Fryer (J. S. C. I., 1893, 107) claim the presence of Thiophene causes the red coloration of Phenol.

Kraemer claims the reddening of Phenol is due to Benzoic Acid.

Sicha attributes it to traces of Copper (J. S. C. I., 1882, 397).



COMBINATION REFLUX AND DIRECT CONDENSER FOR SULPHONATING KETTLE.

Sheet steel tank, 24 in. diam. with 54 ft. to 72 ft. of 2 in. welded pipe coil, tank 4 to 6 ft. high. Can be built for $45.00 to $60.00.

1 sheet of detail drawings of this coil condenser and names of manufacturers who have submitted bids. Price, $10.00.

Also drawings of smaller sized coil condensers and condensers arranged differently.

Kremel, to other metals (Chem. Zeit., 1886, Rep., 14), and also Meyke (Fischers, Jahresber., 1883, 513).

Yvon assumes it to be Rosalic acid (Pharm. J., Trans., 1881, 1051).

Ebell, to other oxidised compounds (Rupert anal. Chem., 1884, 17), also Richardson (J. S. C. I., XII, 415), Bach (Monit. Scient., 4, VIII, 508), Gordon, Boes and Reuter.

Kramer & Spilker (Berl. Ber., 1890, 648) claim the coloration is due to Indene.

## ESTIMATION OF PHENOL (BIBLIOGRAPHY).

Messinger & Vortmann (Ber., 1890, XXIII, 2753).
Riegler (J. S. C. I., 1900, LXXVIII, 112).
Schryver (J. S. C. I., 1899, XVIII, 553).
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## A PROFITABLE ENTERPRISE.

There is probably no other chemical today, that is used in liberal quantities, that has offered the splendid opportunities for investment that Phenol has.

This situation has now existed for one year. Twelve months ago Carbolic Acid was 50c. per pound, and it now sells for $1.50. The price has fluctuated between $1.50 and $1.75 for some time.

At 50c. it was a splendid business opportunity, and then meant a profit of over 30c. per pound. Today this profit is nearly $1.25 per pound, and the demand for it is without limit.

In normal times we import over 3,000 tons annually for technical purposes alone, and these wants have now increased probably 50% without the war requirements.

All stocks of Phenol were long ago exhausted, and what little is now made goes into Picric Acid or into the Salicylates, either of which pays handsomely no matter what the Phenol costs.

It would take 15 plants, each producing one ton of Phenol per day, to take care of the peaceful requirements for Carbolic Acid, not counting the requirements for replenishing the exhausted stocks long since disposed of. Then an equal number of plants could produce Phenol for Picric Acid purposes and make no impression whatever on the Picric Acid demands.

Single requisitions of 1,000 tons of Picric Acid have come to this country without finding a single taker, and one order of this kind would run two Phenol plants, each producing one ton of Phenol per day for 12 months each, and as many more similar orders could be had as wanted just for the asking.

Is there then any other Chemical, in the whole list of needed articles, in which such opportunities have been offered as in Phenol, and the American public today is about as hesitant in taking it up as they were twelve months ago. Any plant that would have been running for the past six months, and producing one ton per day of Phenol, could have made a clean profit of nearly one-half million dollars, and on a plant costing less than $35,000 for land, buildings, power, machinery, apparatus and everything included.

Why then has there been this reluctance to engage in so lucrative an enterprise?

The answer is "ignorance" and the acceptance of the supposition that we really are not able to make the chemicals that

we have been importing. This is equally true in the Aniline industry and probably will continue so, until Chemists and Engineers specialize on separate products, until they out-German the Germans and produce these products better than they have ever been made before, and as cheaply, and which the American people can easily do if they would only think so.

Twelve months ago there was but one Synthetic Phenol plant operating in the United States. After this plant had been running some time successfully and producing Phenol in large commercial quantities, and as late as the early part of February, 1915, it was still called by most outsiders as a farce and failure.

Many weeks elapsed before the public at large would believe that Synthetic Phenol could be made in a commercial way, and not until the National Exhibition of Chemical Industries in New York in September, 1915, when five separate manufacturers exhibited samples of Synthetic Phenol that they were making, was the proof made positive.

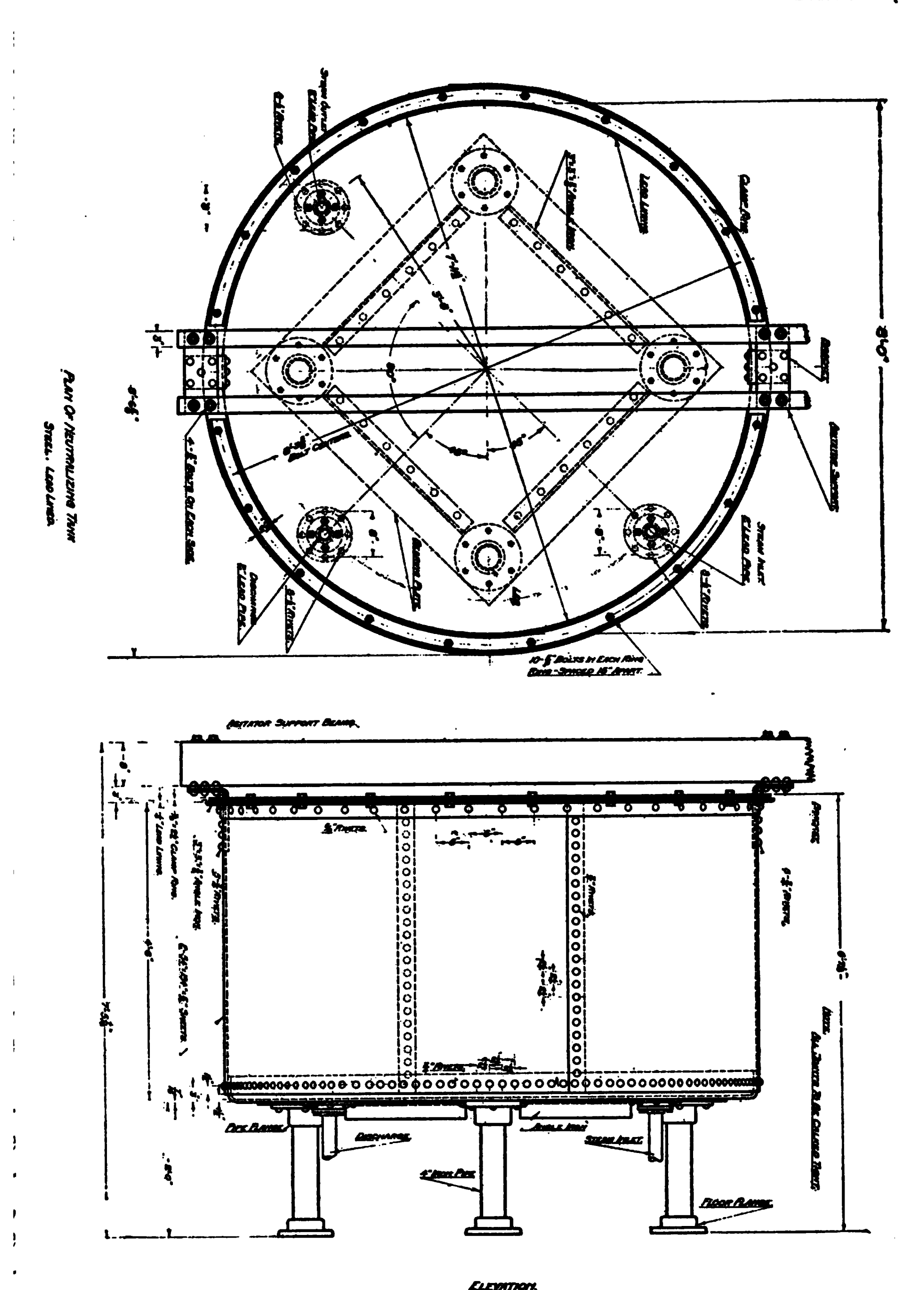
The public then were finally disposed to accept the process as a fact. The display served its purpose, and all doubts were at last removed.

Our other needed Coal-Tar derivatives, Aniline, etc., are just as easily made, many of them far easier than Phenol, but Chemists and Engineers must specialize on some one or two of them, practicalize the chemistry, and devise the necessary apparatus, and make it so that it will be superior to anything the Germans ever dreamed of. The Germans have "buffaloed" the people of the world on their chemical industries, until every one is ready to believe their superiority as an unchangeable fact.

How long is it that American ingenuity has been second to German mechanical conceptions, and how long is it that American inventive genius has been second to any anywhere in the entire world?

Are the German formulas and reactions in the Benzene derivatives any different from the American formulas for the same reactions? Are not the text books and literature on the chemistry of these compounds readily accessible to every American, and does not every chemical and color manufacturer have the opportunity of taking the literature on these products and commercializing their production, through a little ingenuity and mechanical application?

All honor is due the German people for their application and achievements, but we can readily outdo them on these very industries if we make up our minds to really try to do so.



ELEVATION.

SHEET STEEL TANKS, LEAD LINED, WITH AGITATORS, AND SUPPLIED WITH TANK-BENCH HAVING ADJUSTABLE PIPE LEGS.

10 sheets of drawings of steel and wood tanks, all 8 ft. in diameter and various depths, with details of several agitators, tank connections, wood and iron tank-benches, and names of the various manufacturers who are makers, and who have submitted figures. Price $50.00.

## VOLUME OF BUSINESS AND PROFITS.

The volume of business done even in a one-ton synthetic Phenol plant is stupendous and the profits are enormous.

At the present prices of Phenol of $1.50 per pound, a one-ton plant would produce over $3,000 worth of Phenol daily, or over $1,000,000 worth per year.

The profits would be over $2,500 daily, or three-quarters of a million dollars annually.

If such a plant could operate only for two to three weeks it would pay for the entire investment of apparatus, buildings, power and everything else in that time.

It would require about $700 worth of raw materials daily to supply such a plant, and its operating expenses and labor, while amounting to about $50 per day, makes so small a per cent. on the volume of business done, that it is scarcely worth considering.

From 15 to 20 men will operate a one-ton plant, and two tons of coal daily would easily furnish the power.

No matter what price the raw materials may be costing, it would vary the cost of the Phenol not over 3 to 5 cents per pound, and 25 to 30 cents per pound is now about its average cost, leaving a profit of about $1.25 per pound. If the Phenol sold as low as 50 cents per pound the profits would be about $1,000 per day on a one-ton output, and before the selling price can go as low as that the price of the raw materials must correspondingly fall.

It would seem from this that the inducement was sufficient to encourage the starting of enough Synthetic Phenol plants in the United States within six months to supply the world with all the Phenol and Picric Acid that it could consume.

Ignorance of the chemistry of this subject, however, and an inclination to still believe America cannot do what Europe has been doing for years in chemicals, is probably responsible for this dilatory work. On other lines of industry the United States is not so lacking in initiative as we seem to be in chemistry.

The publicity regarding some of the principal essentials of Carbolic Acid manufacture, that it is hoped this pamphlet will be responsible for, should direct attention to a new industry that can be made permanent, for the product can be profitably made in ordinary times, and drive out of the market every trace of

the regular Phenol for the better uses, and where the Cresols must not be present as they are in the most of it, that is not made synthetically.

## THE SYNTHETIC PHENOL PROCESS BY SULPHONATION.

The process of manufacturing synthetic Phenol by sulphonation is as well defined as is the precess of making Aniline Oil or any other chemical compound.

There are countless authorities as to the proper reactions and procedure, and while there are possibilities of proceeding in ways different from the accepted methods, upon practical lines alone, those ways very soon give place to the standard methods of operating.

Many impractical and substitute ways, however, are daily advocated, and for this reason a general outline of the process is here given.

The synthesis of Phenol consists of five separate and distinct reactions, each simple in itself, and beyond question as to its practicability and as to its results.

First—The sulphonation of Benzol to Monosulphonic acid.

Second—The conversion of the Benzene Sulphonic Acid into a Calcium Salt solution.

Third—Converting the Calcium Salt solution into a Sodium Salt solution.

Fourth—Fusing this Sodium Salt when dried, with Caustic Soda, to produce Sodium Phenolate.

Fifth—Decomposing the resultant Sodium Phenolate with a mineral acid to liberate the Phenol.

The balance of the process consists in mechanical operations, merely to facilitate these five reactions.

Nearly every inexperienced person contemplating the production of synthetic Phenol, believes that he can do it differently, and this in face of the fact that the entire world today is producing Phenol in precisely the above manner.

On sulphonation there is at present no question whatever as to the method of procedure.

$$C_6H_6 + H_2SO_4 = C_6H_5SO_3H + H_2O$$

Quantities and strengths of the Sulphuric Acid may vary,

but some form of sulphonation must result.

Concentrated Sulphuric Acid is used and not Fuming Acid (Oleum). Fuming Sulphuric Acid is liable to change not only a part of the Benzol, but its Monosulphonic acid also into a mixture of meta- and para-disulphonic acids.

Considerable quantities of the meta-acid are formed even at lower temperatures should an excess of Fuming-acid be present.

Higher temperatures or prolonged heating, even with concentrated Sulphuric Acid, will form a mixture of both mono- and disulphonic acids.

The evolution of Sulphur Dioxide in sulphonation, indicates an oxidation and consequent destruction of a portion of the substance that is being sulphonated.

It is the Chemical Engineer's business then to tell and show you just what is the best and most practical method of procedure in sulphonation, to produce the desired Benzene-monosulphonic acid, which alone can be eventually converted into Phenol.

The production of the Sodium salt has offered many opportunities for departures from correct methods, and so numerous recommendations are continually being found for the production of the Sodium salt direct, rather than from the Calcium salt that should be made first.

It is true that the Benzene sulphonic acid can be converted into the Sodium salt direct, as for instance, by using Soda Ash (Sodium Carbonate) for both neutralizing and conversion, as per the following formula:

$$2(C_6 H_5 S O_3 H) + Na_2 C O_3 = 2(C_6 H_5 S O_3 Na) + C O_2 + H_2 O$$

$$H_2 S O_4 + Na_2 C O_3 = Na_2 S O_4 + C O_2 + H_2 O$$

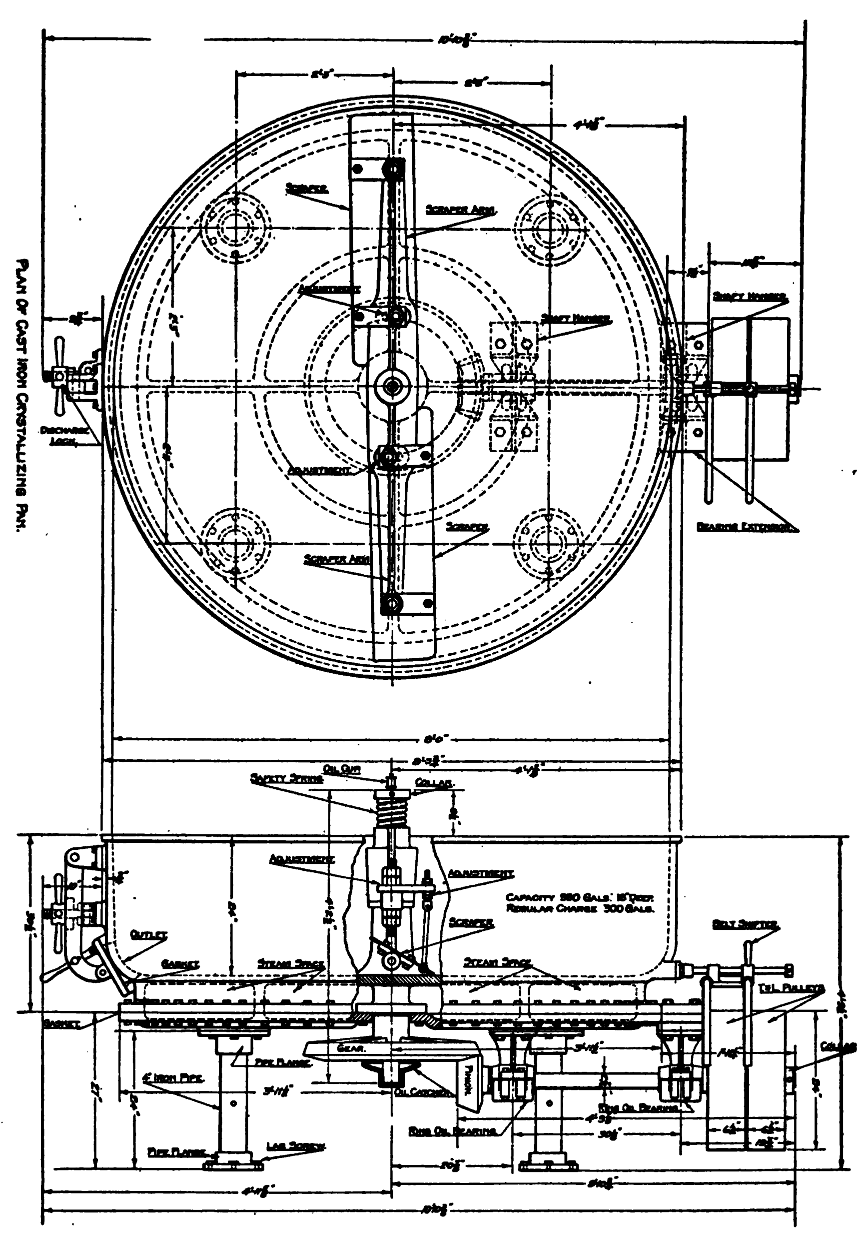
or by using Salt solutions (Sodium Chloride) for the same purpose, but while it is possible to do this it is very impractical.

$$C_6 H_3 S O_3 H + Na Cl = C_6 H_5 S O_3 Na + H Cl$$

$$H_2 S O_4 + 2(Na Cl) = Na_2 S O_4 + 2(H Cl)$$

In the former case the evolution of $C O_2$ would greatly hinder the operation, and the quantity of Sodium Carbonate necessary would make the cost prohibitive.

In the latter case the evolution of Hydrochloric acid fumes



PLAN OF CAST IRON CRYSTALLIZING PAN.

ELEVATION OF CAST IRON CRYSTALLIZING PAN.

CAST IRON, JACKETED, CIRCULAR, CRYSTALLIZING PAN, WITH ADJUSTABLE STIRRING DEVICE AND AUTOMATIC DISCHARGE.

8 ft. in diameter, 2 ft. deep, stands 5½ ft. high, capacity 550 gal., weight 12,000 lbs., can be built for $900.00 including pattern work.

8 sheets of detail drawings and names of manufacturers who have submitted bids. Price, $100.00.

would endanger the lives of the operators, and destroy portions of the apparatus, or make necessary the construction of much expensive apparatus additional to the real requirements of a Synthetic Phenol plant.

The correct use of Lime in neutralizing is not for the purpose of preparing a Calcium salt solution, but for the purpose of quickly and cheaply getting rid of the excess Sulphuric Acid.

$$H_2SO_4 + Ca(OH)_2 = CaSO_4 + 2(H_2O)$$

The production of the Calcium salt is merely incidental to this purpose and unavoidable.

$$2(C_6H_5SO_3H) + Ca(OH)_2 = (C_6H_5SO_3)_2Ca + 2(H_2O)$$

After this it is then an easy matter to produce the Sodium salt from the Calcium salt and no evolution of $CO_2$ or noxious vapors accompanies either of these proper reactions.

$$(C_6H_5SO_3)_2Ca + Na_2CO_3 = 2(C_6H_5SO_3Na) + CaCO_3$$

This production of the Sodium salt, finally dry and in suitable condition, and appropriate quantities ready for fusion with Caustic Soda, are important steps and the methods for effecting them should be recommended by a competent Engineer having extended experience in this particular work.

The fusion of the Benzene monosulphonic acid with Caustic Soda is probably the most important portion of the Synthetic Phenol process. It also is probably the most unsatisfactory portion under the methods that have generally prevailed in the past.

$$C_6H_5SO_3Na + 2(NaOH) = C_6H_5ONa + Na_2SO_3 + H_2O$$

The Caustic Soda melting at 590° F. has usually been stirred in open kettles where the contents could spatter and become dangerous in case of burns. The melt has been ladled by hand much like molten lead, and the vapors that escaped have undoubtedly cut down the per cent. of yield materially.

Frequently recommendations are found advocating the separation of the products of fusion in the hot open fusion kettle, and the skimming off of one and leaving of the other.

These products are Sodium Phenolate, Sodium Sulphite and excess Caustic. These under some circumstances will separate

as two different layers, and while theoretically their separation is possible, it is readily seen that such a procedure is impractical and even dangerous.

The most approved methods of procedure and now coming into general use, are to fuse in closed Autoclaves and discharge the fused contents by pneumatic pressure when the reaction is completed. This is followed by dissolving the melt in a closed unit and thus conserve the vapors and obviate all the hand work.

Here again the competent Engineer's services are very necessary to avoid the frequent errors and usual methods of unsatisfactory fusion, and provide instead a thoroughly practical and safe means of producing the Sodium phenolate and its subsequent aqueous solution.

The Sodium Sulphite and excess Caustic readily eliminate themselves under the acidification or decomposition of the aqueous melt and so the safe and economical fusion is quite different from the ways that have been so frequently advocated and followed in the past.

The last reaction of the process is the acidification of the dissolved melt and the decomposing of the Sodium Phenolate into Phenol and Sodium Sulphate.

$$2(C_6H_5ONa) + H_2SO_4 = 2(C_6H_5OH) + Na_2SO_4$$

$$2(NaOH) + H_2SO_4 = Na_2SO_4 + 2(H_2O)$$

The reaction can be accomplished by the use of any mineral acid. Carbonic Acid is mentioned in much of the literature and advocated by various people, but there are numerous reasons for not making use of it, and good reasons for using Sulphuric Acid instead. In case it is used the reactions are as follows:

$$2(C_6H_5ONa) + CO_2 + H_2O = 2(C_6H_5OH) + Na_2CO_3$$

$$2(NaOH) + CO_2 = Na_2CO_3 + H_2O$$

The Engineer again is necessary in directing the proper procedure, and his process must minimize the evolution of $SO_2$ and prevent the loss of Phenol in the Sulphite and Sulphate solutions that are discarded. His design of apparatus must effect the separation of the Phenol with as little change of the Sulphite into Sulphate as possible and with a minimum amount of acid. Such change in the Sulphite is shown in the following reaction:

$$Na_2 S O_3 + H_2 S O_4 = Na_2 S O_4 + S O_2 + H_2 O$$

$$Na_2 S O_3 + C O_2 = Na_2 C O_3 + S O_2$$

The saving of by-products is frequently attempted by many and much effort is often made toward bending the process to this end.

There are no by-products, aside from Calcium Carbonate, that are worth while making any effort upon. This carbonate can be used to take the place of a portion of the Lime, but the others should all be discarded. They consist of Calcium Sulphate cake, and a mixture of Sodium Sulphite and Sulphate solutions, and the recoverable portions would cost more in the recovery than they are really worth.

Such Calcium Carbonate as is used in the neutralizing of the Benzenesulphonic Acid, and excess Sulphuric acid, is represented by the following formula:

$$2(C_6 H_5 S O_3 H) + Ca C O_3 = (C_6 H_5 S O_3)_2 Ca + C O_2 + H_2 O$$

$$H_2 S O_4 + Ca C O_3 = Ca S O_4 + C O_2 + H_2 O$$

There should be no departures then from the accepted methods that experience has taught, and a competent Chemical Engineer is necessary in putting these methods into workable condition for you.

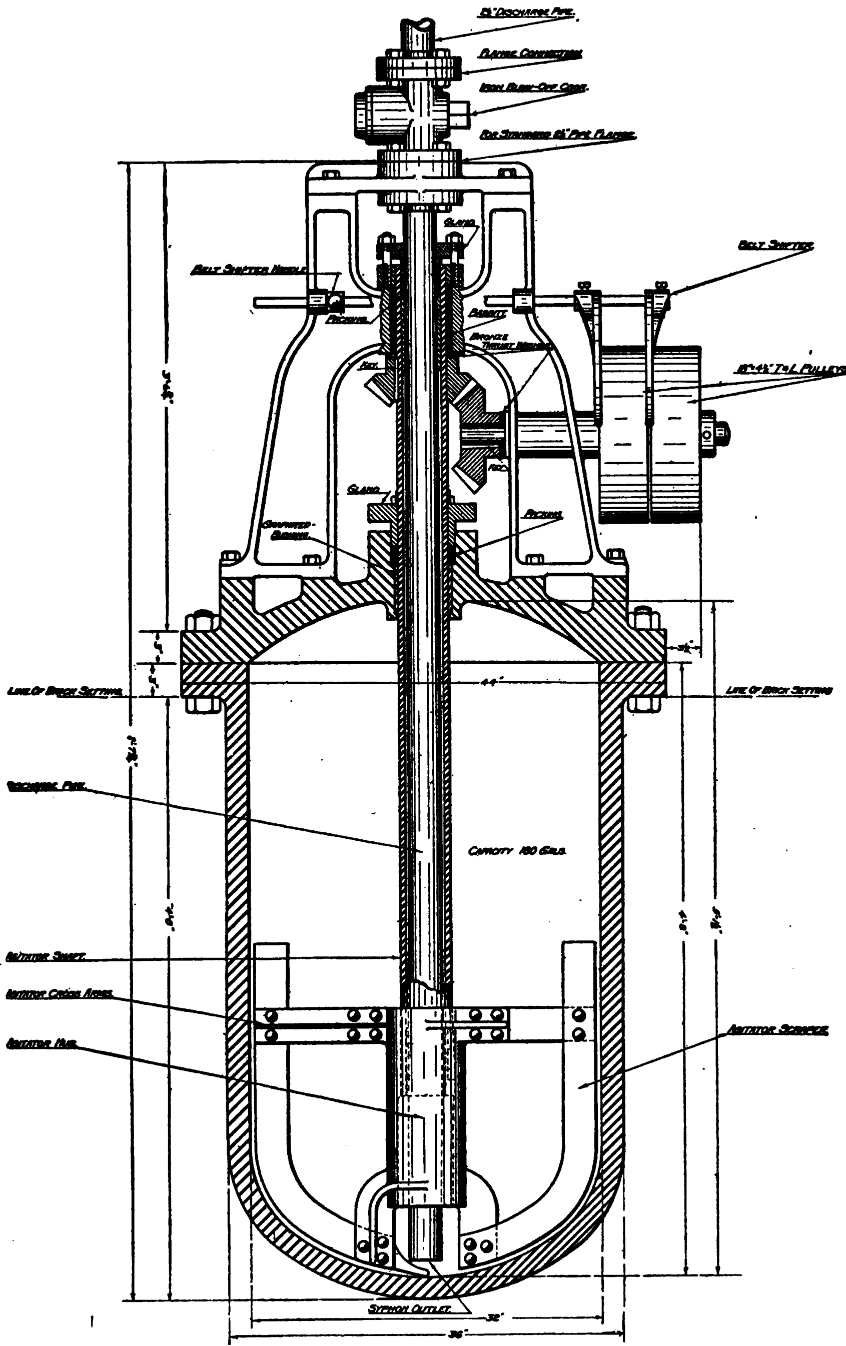
The production of Synthetic Phenol then through the sulphonation method is thus very clearly defined.

From a chemical standpoint the production of Phenol from Benzol is the substitution of the hydroxyl (O H) for one of the Hydrogen atoms of the Benzol.

Benzol is $C_6 H_6$. Sulphonation replaces one atom of H with the sulphonic group $S O_3 H$. One such replacement produces a Mono-sulphonic acid. If two Hydrogen atoms are replaced the result is a Di-sulphonic acid. No Carbolic Acid will result from the Di-sulphonic Acid, as that is the starting point for Resorcinol by the same means, and so the sulphonation must be properly done.

The procedure is then to replace the Sulphonic group ($S O_3 H$) by the Hydroxyl group (O H).

This can be best done if the Benzene Sulphonic Acid is converted into a Sodium salt, and the Sodium Salt is easiest produced by first producing the Calcium Salt.



CAST STEEL AUTOCLAVE, WITH AGITATOR, CLOSED TOP, SYPHON DISCHARGE, TO SET IN BRICK.

**180 gal. capacity, stands 500 lbs. working pressure, 32 inches diameter, 56 inches deep, 2 inch walls, height 8 ft. 8 in., weight 6,500 lbs., can be built for $800.00, including pattern work.**

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The O H then of the Caustic replaces the $S O_3 H$ of the Sodium Benzene Sulphonate, and upon decomposing the Sodium Phenolate that results from the fusion, the Phenol is liberated.

Its formula is $C_6 H_5 O H$ and it is of a weak acid nature.

The process is in reality a very simple chemical procedure. Each reaction is clean-cut and definite. There is very little opportunity of "getting by" on anything.

In suphonation, the disulphonate is easily avoidable; in the other reactions only one result can possibly happen.

The process then rests largely on Engineering to make it a commercial and practical success, and the opportunities are numerous for the display of ingenuity to effect the mechanical processes in the best and most practical manner.

The Chemistry is fixed and definite, the apparatus and procedure open to a multiplicity of ways, and the success of the proposition in a financial way rests entirely with the Engineer who designs and plans the plant.

## RAW MATERIALS.

The raw materials for the production of Synthetic Phenol are concentrated Sulphuric Acid, Benzol, Caustic Soda, Soda Ash, and Lime. A part of the Concentrated Acid may be replaced by weak Chamber Acid.

In round figures you can estimate these materials as follows:

4 tons of Sulphuric Acid 98%
1½ tons of Caustic Soda
1 ton of Sodium Carbonate (Soda Ash)
2 tons of slacked Lime
340 gals. of Benzol (2,500 lbs.)

A sufficient amount of Calcium Carbonate is produced in the process, as a by-product, to cut down the Lime required to about one-half the above amount.

No other by-products are recovered, or are worth recovering. They consist of Calcium Sulphate cake, (Gypsum) about 3 tons, Sodium Sulfite and Sodium Sulfate mixed and in solution about 3 tons, Carbonic Acid, and $S O_2$.

The amount of Crystalline and pure Phenol from the above materials is a little over 1 ton.

An 85% yield on the weight of Benzol used is readily obtainable. Higher or lower yields depend upon the purity of the Benzol, and the methods employed in the various reactions and

mechanical operations.

Undue effort is not usually made for high yields, but rather to quantity of output.

## BENZOL.

Benzol is the fundamental necessity of not only Phenol and Picric Acid, but of Aniline Oil and the general color industry as well.

Before the war, our Benzol production in the United States was comparatively small, and millions of dollars worth of this product, and its allied coal-tar derivatives, went up in smoke and vapors, and were lost to the entire world.

Probably no branch of the new chemical industries has responded so valiantly to the wants of the American people as have some of the large steel, coke and similar industries within the past few months on Benzol.

No more bee-hive coke ovens will ever be built. Retort ovens produce more and better coke, and save the vapors.

Gas scrubbers now recover the Benzol and its related products from the gas, before it leaves the producing plants.

Single plants have sprung up in the past few months producing 2,000, 3,000, 5,000 and 7,000 gallons of Benzol per day, that produced none whatever before the war.

Benzol selling at 70 cents per gallon in November, could be produced at 6 cents per gallon under some of the modern methods, and was actually being made at those figures in some places.

Benzol producers even today are figuring and planning on diverting this product to automobile use, in place of Gasoline, as soon as the war is over, and they will be well able to do so, and easily compete with it.

At present the demand is great, but the supply will soon be enormous. No contracts should be made, but depend on the open market, and while the sale of Benzol now is largely in the hands of one prominent firm, they realize that American industries must be properly taken care of, and they have tried to do this from the very start. While the profits in Benzol are large right now, these are bound soon to assume more reasonable figures.

Under a proper understanding then of the Benzol situation, no fear need be felt as to obtaining the necessary amount for use in making Phenol.

## SULPHURIC ACID.

The price of concentrated Sulphuric Acid has been quite high. A large amount of it is being exported, but American producers have now begun to realize that by taking care of home industries they are building up a future profitable business connection, whereas the war requirements are liable to leave them without business at any time.

Numerous concentrating plants have recently been put in, and many new acid plants have been started. The raw materials for Sulphuric Acid are readily obtainable in any amount, and the investment for manufacturing it is not large. It is an enormous industry and one that must scatter itself to all parts of the country and not centralize at any one point, on account of transportation expenses.

For these reasons, it is now possible to obtain the necessary acid and without any contracts whatever. A contract can be of little benefit to the buyer on an easier market and with falling prices. I am prepared to negotiate your acid supply if you cannot do so yourself, or will furnish you a list of all the acid manufacturers in the United States with whom you can correspond direct. These numerous inquiries, however, that result in no business, do not tend to make the acid man very solicitous as to your wants, when he can sell all that he produces, abroad without discussion. So long as this condition remains, it might be well for the Engineer to do the negotiating for you.

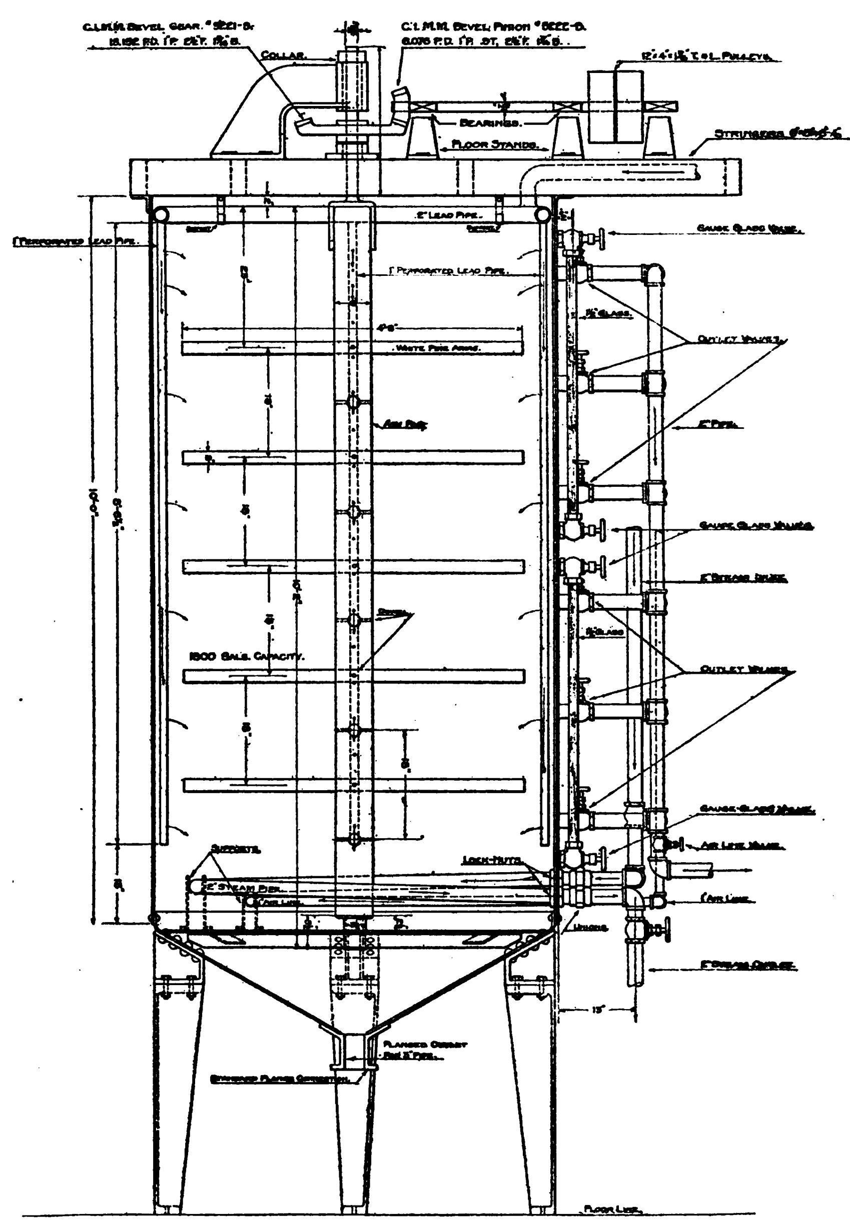
The price of acid will be the market price, which will vary from time to time and when it drops you can obtain the benefit. So long as others pay the same, you are being treated fair.

All new enterprises will pay a higher price under a contract, than they will on the open market. Their only gain is certainty of scheduled shipments.

The only ones benefited under acid contracts are established chemical houses who have been customers of long standing, and with definite wants at all times. These people have been able to increase their contracts frequently under very favorable terms.

No undue concern should be felt now as to the Sulphuric Acid requirements for the manufacture of Synthetic Phenol.

Sulphuric Acid of any strength above 92% can be used, but




SHEET STEEL SEPARATION TANK.

**Stands 14 ft. high, 5½ ft. in diameter, with agitator, gauge glasses, air and steam coils, open or closed top, weight 4,000 lbs., can be built for $250.00.**

**8 sheets of detail drawings with names and bids of various manufacturers. Price, $100.00.**

a much larger amount of it is necessary than to use 98%. Oleum or Fuming Sulphuric Acid is not necessary in the sulphonation and is only used to strengthen weaker Sulphuric Acid before it is added to the Benzol.

## CAUSTIC SODA.

Because of the apparent scarcity of Caustic Soda, in November and December a letter was sent to every Caustic Soda dealer and manufacturer in the United States, enquiring as to prices, and the outlook for Caustic for such Phenol plants as might be interested in purchasing it in the early months to come.

Assurance was given by the most of these people that all home wants would be supplied.

A very large export business is at present being done in Caustic Soda, but when the price is as high as it now is, it is a comparatively easy matter to start a Caustic plant anywhere and produce, at little outlay, a grade of Caustic that is salable and profitable as well. The raw materials are not high, and while the tendency of all these replies was toward holding the price as high as possible, the letters as a whole showed a weakness in the high demands, and a falling price is sure to follow in the early future.

No contracts should be made on Caustic, but purchase in the open market and be free when the price really begins to decline.

## CHAMBER ACID.

Chamber Acid, to use in place of concentrated in a portion of the process, is readily obtainable and at a low price. The ordinary agricultural acid is sufficiently good for the purpose, and the requirements are more than covered in the total estimate for the concentrated.

## SODIUM CARBONATE AND LIME.

These materials are not difficult to obtain at any time, and while Soda Ash is now a little high, the amount required is not very large.

Lime is obtainable anywhere at any time and the price is low.

## BUILDINGS.

Buildings suitable for a Phenol plant can be of most any type or kind of construction.

Probably no two plants will ever be constructed alike.

The process can be installed as a two-level process (2 stories), or as a one-level process. The most desirable arrangement is to start the process at one end of a building and finish at the other end of the same, or a separate building, that is built in line with the first and located say 20 ft. from it (end to end).

40 to 46 ft. wide lends itself best to the general arrangement.

If the plant is a 1 to 5-ton plant, 145 to 160 ft. in length by the above width is the requirement of the larger building, and 60 to 80 ft. long by the same width is the size of the smaller building. The two are connected end to end by a covered platform 20 ft. long and a continuous line shaft runs through both of them.

This sized plant would be two stories, the lower floor 11 ft. high and the upper floor 14 ft. high in the clear.

A gable roof 7 ft. pitch is best and an open monitor or louver for ventilation throughout the length of both buildings at the top is necessary, for disposal of the steam and vapors.

The floors should be wood and 3½ to 4 ft. above the ground.

A Boiler house should be built outside of these two structures, and the Engine is located in the larger building.

The above plant would be equipped with sufficient apparatus to produce 1 ton of Phenol in 10 hours and space left at each unit to allow of the necessary additional units being later installed to double the plant's capacity at any time.

By running the plant two shifts in 24 hours, the capacity would again be doubled, and as every unit permits of 25% additional capacity as maximum, it allows then of a further increase and thus a 1-ton plant can be converted into a 5-ton plant whenever it is wanted, and at very little additional expense.

A 500-lb. plant requires a one-story building 120 ft. by 40 ft. with an attached boiler room 30x32 ft.

The floor sets 3½ to 4 ft. off the ground in the factory proper, and the boiler room has brick floor right on the ground.

The height in the clear is 15 ft. in the factory. Gable roof, louvers and plenty of windows are required, the same as in the larger plant.

These various sized plants can be constructed of wooden frame work covered with galvanized and corrugated iron, or wood throughout, or of brick with steel interior frame work, or in any of the prevalent forms of construction.

The smaller plant is best made of concrete block and galvanized iron roof.

Of course, any building with high enough ceilings can be utilized, but as the plant is comparatively large, it is usually best to construct the buildings especially for the work, as the interior can then be adapted more readily to the processes.

Old buildings usually do not have high enough ceilings and do not permit of heavy tanks being placed as they properly should be.

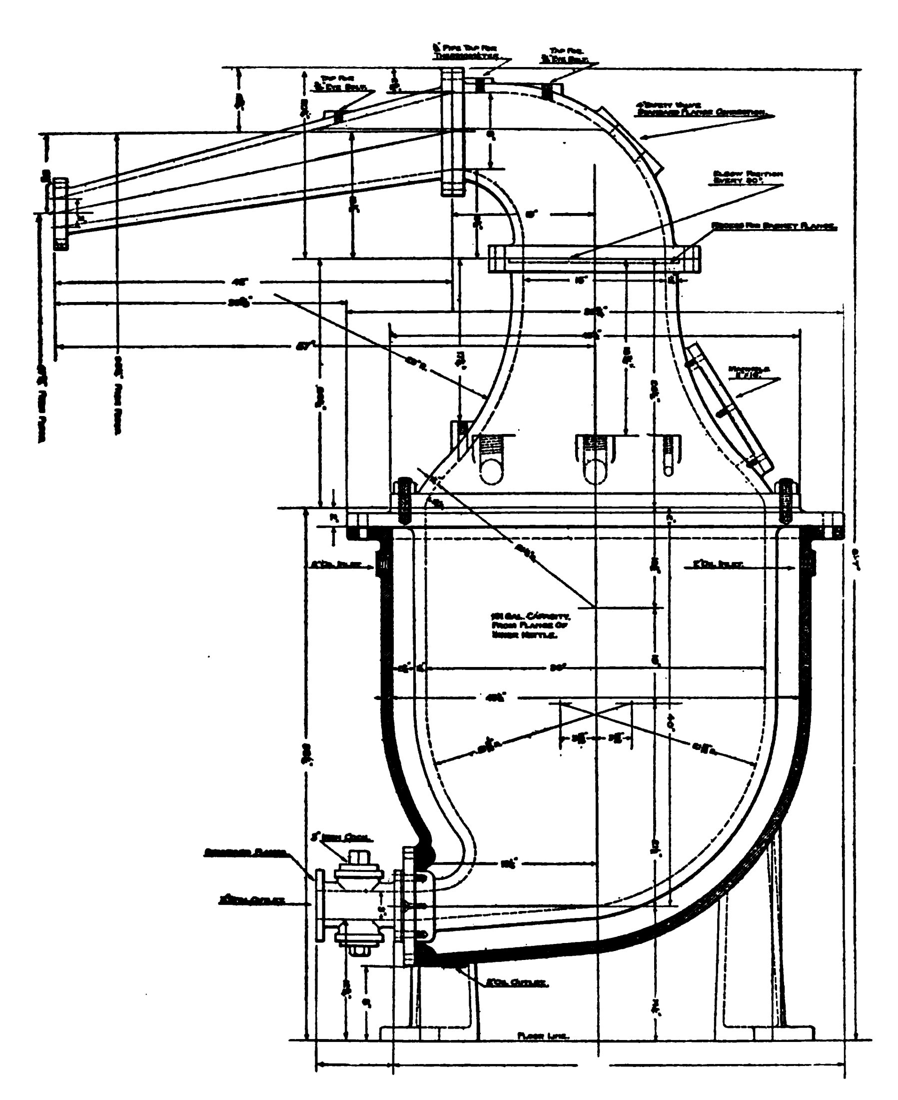
## POWER.

A one-ton Synthetic Phenol plant (producing 1 ton of Phenol every 24 hours) will require a 60x16 or 66x16 boiler (80-100 H. P.). The latter will permit of operating easily on 80 lbs. of steam.

A 50 to 60 H. P. ordinary slide valve Engine will drive all the agitators, mills, compressors and their necessary shafting.

The steam power is required to operate the engine, pumps, steam heating coils in the tanks, heat the jackets of kettles, supply hot water, dissolve some of the products and for general heating purposes.

The engine must drive the main shaft, the counter shafts, the numerous agitators, the grinding mills, the air compressor, elevator, pumps and other usual shop equipment.



CAST IRON, OIL JACKETED, CARBOLIC ACID STILL.

**150 gal. capacity, weight 7,000 lbs., height 8 ft. 8 in., diameter at flange 52 inches, can be built for $475.00 including pattern work.**

**8 sheets of detail drawings for above still and names of manufacturers who have submitted bids. Price, $100.00.**

**Also drawings of same Still, 90 gal. capacity, and of either size without Jacket to set in brick for direct fire.**

**Details of extension heads of any height for either of these Stills are included.**

## MOTORS.

No electric motors are recommended in the Phenol plant and as little use of electricity as possible.

## THE APPARATUS.

Very little stock apparatus can be used.

The filling charges are quite large for each unit, and heating and agitation usually necessary at every step.

This means specially designed units for practically everything.

No stoneware, glass or pottery of any kind is required.

Only one tank really requires a lead lining, the balance may be wood and can be obtained most anywhere.

No special metal is necessarily needed, either for the acids or the resultant products, though use can be made of such if it is wanted.

After neutralization, the product is harmless and has no effect on metal or the skin until fusion.

None of the operations beside sulphonating require a lengthy period of time.

With the opportunity, then, for unlimited conception of means and methods for handling the various processes, the designing of the apparatus becomes a very complex question.

A plant may be operated by high-pressure steam, or by low-pressure steam, according to which is readiest obtainable.

At a Benzol plant there is plenty of hot oil that can produce nearly all the heat that may be required.

At some other large manufacturing point exhaust steam might handle nearly everything.

Evaporation may be carried on in open tanks, in multiple effect evaporators, or in ordinary tubular boiler installations, where the steam of evaporation is utilized in operating the balance of the plant, the same as from the use of clear water.

Drying of the crystalline products can be done in pans over fire, by steam jacket, or by hot oil heat. The pans are tended by hand, or circular evaporating pans can be used that do their own stirring and discharging without any hand labor whatever.

Fusion can be carried on in open kettles or in closed autoclaves.

The fused mass or melt can be ladled by hand, or handled by pneumatic pressure in closed tanks and pipe lines.

The fluids can be conveyed by pumps or by air pressure.

The cake from the Filter Presses can be handled automatically, with no hand work whatever, or be handled in the usual way by dumping and carting.

Agitators run fast and run slow, each stage of the process requiring a different type.

Syphon discharge to kettles and autoclaves can replace the older and more familiar ways.

Distillation is effected by fire, by steam or by hot oil.

Manipulation of all the fluids can be in the open, or in airtight pipes and receptacles.

Thermometers and pressure gauges can be of the old type, or of the modern recording, indicating and alarm kind.

Every minute of the operation can be shown on a record, giving time, pressure and temperature, that can be preserved.

Automatic devices can register each mechanical step of the entire plant and all these devices to govern or keep check upon the work, can indicate, both at the unit for the operator, and also at a distance for the Director.

With all these variations and possibilities then, there is no such thing as a stereotyped plan for a Phenol plant.

The Engineer's function is to present all these various ways, explain and illustrate each in full, show the utility and cost of each and then leave the Client to intelligently select the principal features that appeal to him the most.

After this decision, plans for the arrangement of the plant and construction of the several units must be made, and so each plant becomes entirely different from any other that has preceded it, except for the smaller parts.

Each piece of apparatus is designed to be built in any Foundry, Machine Shop or Boiler Making Plant anywhere.

All the cast-iron kettles are sweep work and require no large patterns.

As most of the items are quite large, it means that the machined surfaces require large lathes, or boring mills, to handle them.

The sheet steel tanks are readily made in any locality and well detailed shop drawings are provided for everything.

Pumps, pipe and fittings are the usual stock that is on sale in every supply depot in the country.

Wooden tanks are usually 3" cypress and obtainable most anywhere.

The legs on every item are adjustable, so that the unit can be accurately plumbed, or tilted toward the outlets, as may be required.

Condensers are of every kind and type that can be thought of.

Crude Oils are used for burning in open fires. High flash oils are used in heating some portions by circulation and cheaper low flash oils for heating in other places by the same means.

## THE CHEMIST.

A competent Chemist should at all times be in charge of the chemical portion of the work. Upon him rests the full responsibility of yield and profitable production.

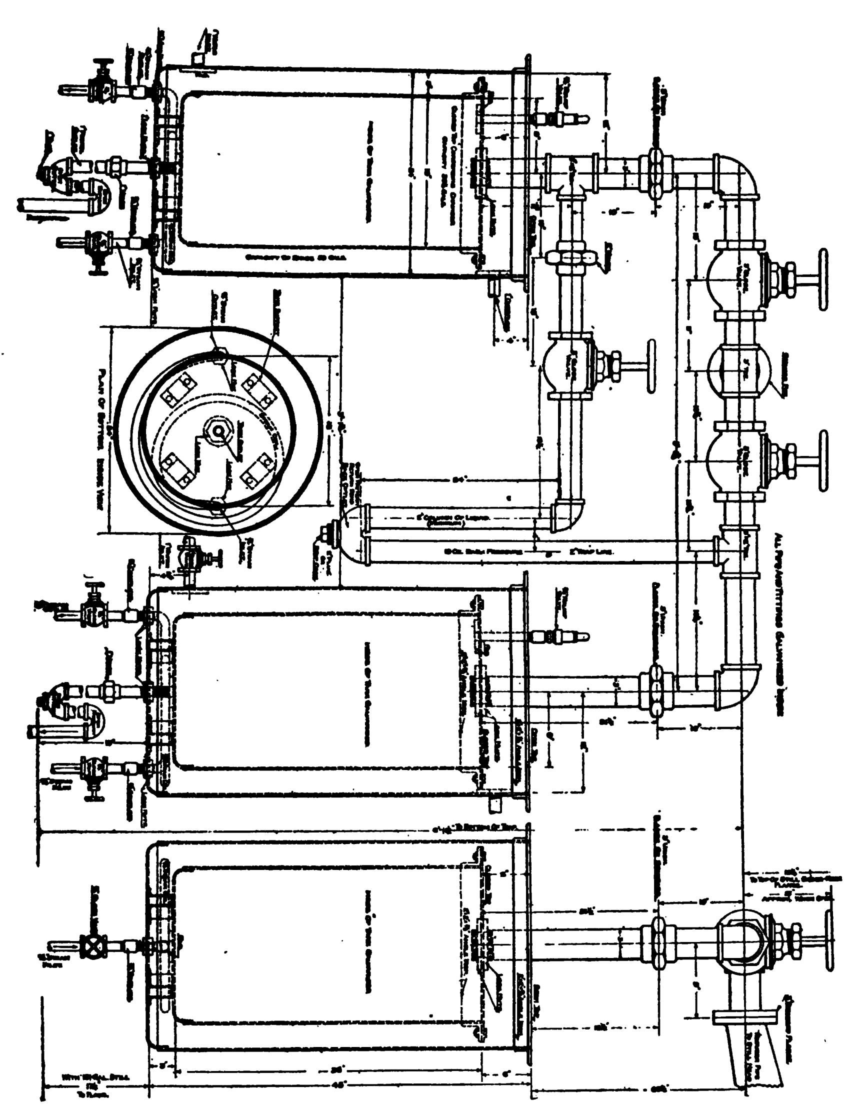
Any technical graduate is sufficiently prepared to handle the work understandingly, and a younger man will be more desirable than some of the older ones, as there is a lot of real work to do that requires energy and ambition. There is little use in a Phenol plant for the old deliberative student or would-be scientist.

## THE SUPERINTENDENT.

He should be of the usual type that is found in any of the other manufacturing enterprises. Youngish, strong, a student of human nature, who can handle help and knows how to do things, and who will always keep the plant moving. One that is ever ready to anticipate the troubles and difficulties of apparatus and operation, and with a remedy thought out before it is ever really needed.

"Rough-necks" will constitute a good part of the labor and it needs a real man to handle them, see that they are doing their duty, and at the same time protect them from the risks and dangers that the inexperienced are always subjected to. The welfare of the help is as necessary in a Phenol plant as is the correct operation of the best piece of mechanism that the plant holds, and it is the Superintendent who must provide all this.

Of course, the Superintendent and the Chemist must pull



TWIN CHAMBER, SHEET STEEL, CARBOLIC ACID STILL CONDENSERS.

Diameter of inside tank 18 inches, outside tank 24 inches, capacity 39 gal. each. Made of sheet steel, can be built for $70.00 per pair of double tanks (4 tanks).

2 sheets of detail drawings for above pair of condensers and names of manufacturers who have submitted bids. Price, $20.00.

Also drawings of Jacketed Coil, or plain coil condenser for same purpose.

together, for each is dependent on the other. One man can not efficiently fill the place of both.

## NUMBER OF SYNTHETIC PHENOL PLANTS IN THE UNITED STATES.

There are probably over a dozen Synthetic Phenol plants either in operation or in course of construction today in the United States.

The most of these are intended for Picric Acid, and so the field is practically clear for general technical purposes.

Many plants that have been reported as preparing for Phenol have ended at merely the report and some few that have attempted it have failed entirely to produce.

The largest producer so far uses the most of their Phenol in their own business. One Chemical Company who produces the best grade made today, use the larger part of their product in Pharmaceutical preparations.

Several plants at this writing are incomplete and will not be in position to produce for several weeks to come.

There is room for 25 one-ton Phenol plants in the country today, and plenty of raw materials obtainable to run them all.

## COST OF A PHENOL PLANT.

A Synthetic Phenol plant is not a very expensive manufacturing project.

The apparatus and its installation for a plant producing 500 lbs. of Phenol per day can be brought down to as low a cost as $10,000.

The plant's capacity can be doubled for 25% additional cost. This small plant would expect to purchase its rectified Benzol rather than to rectify it.

A one-ton plant including a Benzol Rectifier would cost for the apparatus and its installation from $18,000 to $20,000 when put in on an economical basis, but $40,000 could be spent in making this a five-ton plant to include all the improvements and devices that are now known.

Additional to the apparatus and installation work, would be the buildings, power and the Engineer's services, on either of the above installations.

## DANGERS IN MANUFACTURING.

Under modern methods, and with suitable apparatus, there are no dangers connected with the manufacture of Synthetic Phenol, beyond the usual risks of any factory work.

If men put their fingers into running gears they will get hurt, or if they let hot water or steam run onto themselves they will get scalded, but outside of the "fool accidents" of this kind, there need be none, if the plant is arranged properly from the start.

The only risks that could cause accidents, incident to this particular industry, are escaping Benzol vapors that might explode if they came in contact with flame, Sulphuric Acid burns in carelessly handling acid, Caustic Soda burns from obsolete methods of Caustic manipulation, and Carbolic Acid burns from reckless handling of the final product.

No gaseous products harmful to any one are given off at any stage of the process under the generally accepted methods, and no fumes of any kind are going to disturb the neighborhood.

To obviate the possible Benzol vapors, the rectification is done in an outside building with no communication to the main part.

The Sulphonation while done inside, discharges into tanks outdoors in the open air first, to permit all vapors to escape, and when it is then conducted inside to the neutralizing tanks, there can be no dangers from explosion.

Carbonic Acid gas and air pressure move all the fluids, acids, etc., in closed pipes, and so no undue dangers of Sulphuric Acid burns are present.

Caustic Soda fusion is conducted in sealed Autoclaves, discharged by pneumatic pressure, and all the subsequent operations are conducted in air-tight tanks, apparatus and pipe lines, and handled automatically without any hand labor whatever, thus eliminating all risks of every kind, and the purified and refined Phenol is finally drawn off from the storage tanks into the final shipping packages without having been subjected to exposure at any time.

No experimental work is necessary and so no untried chemical methods are expected, that may create difficulties of an unknown kind.

## BETA NAPHTHOL.

A Synthetic Phenol plant is likewise suitable for the manufacture of Beta Naphthol.

If Autoclave fusion is already installed the only change is to Autoclave-sulphonation, in place of the Kettle and Reflux Condenser type used with Benzol.

Beta Naphthol is made from Naphthalene by sulphonation, and then fusing the Sodium Salt with Caustic Soda.

The price, costs and profits compare favorably with the manufacture of Phenol.

Installations for Beta Naphthol will be made at the same charges as for Phenol.

## MY ENTRY INTO SYNTHETIC PHENOL.

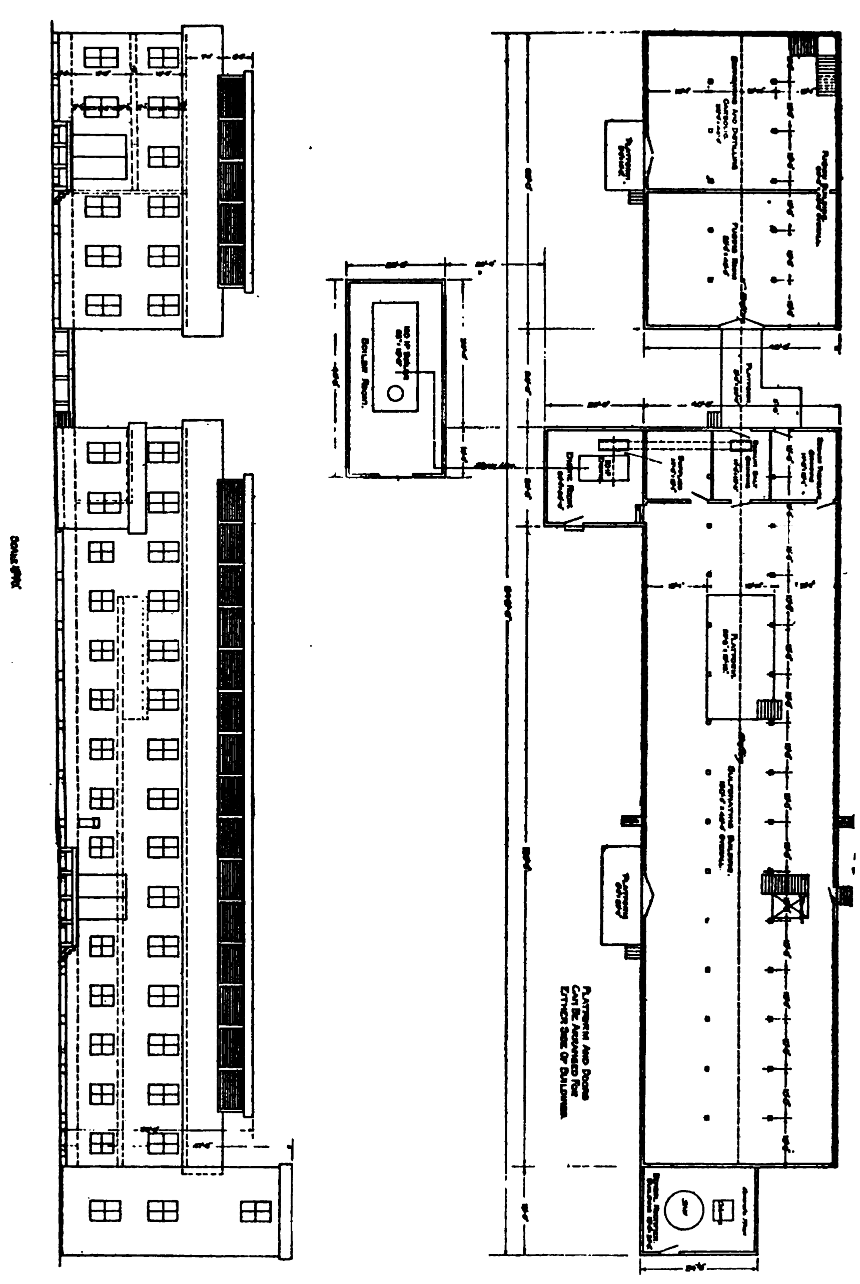
Late in 1914 I had finished a four-volume work on China Wood Oil. A compilation that was largely obtained from the leading foreign Chemical and Technical Journals, Patents and other publications.

Having already had considerable practical experience in the technical uses of Phenol, in Synthetic Resins and in Phenol-Casein-Thermoplastics, the war situation seemed propitious for taking up some one or two of the Coal Tar by-products and specializing on these until they were developed to their full limit. My researches already covering about eighteen months in the Chemical and Technical literature, served to quickly put me in touch with all the information that there was on Synthetic Phenol.

The extensive data on Casein-Phenol and Phenol-Aldehydes that I had gathered during some ten months' association with that particular work also proved of material benefit, and in the early part of 1915 I entered into the first contract to install a Synthetic Phenol plant, to be erected near New York City.

This was one of the first projects of the kind to be started in the United States outside of the one previously mentioned. A plant in Syracuse and one at Rahway, N. J., were started shortly after, or about this time, by their owners.

Since this date my entire time has been given to designing



GROUND PLAN AND SIDE ELEVATION, FOR TWO TON PHENOL PLANT, WITH BENZOL RECTIFIER AND SEPARATE BOILER ROOM.

Buildings 248 ft. long (over all), 40 ft. wide and 25½ ft. high on sides.

apparatus and working out the most approved methods of its installation, for the production of Synthetic Phenol.

With the assistance of a corps of competent Engineers, Draftsmen and Chemists I have originated and designed considerable apparatus that is entirely new to this art. The German and English manufacturers make use of none of the modern devices and appliances that have already been put into use in this country.

Entirely new principles of operation, of heating, handling, labor saving, conserving gases and wastes, eliminating of dangers and risks, and increasing yield have been introduced.

A year's diligent study with proper assistants, and with opportunities for trying any ideas that might have merit, and with people willing to pay the price if the idea worked, all these have produced results, and these results are, that a complete Phenol plant can now be designed and installed, that will be superior in its operation to any plant that exists today in Europe, and that will cost much less than if built under any other Engineering plan, than the one that I am following.

## MY METHOD AND PLAN OF ACTING AS YOUR CHEMICAL ENGINEER.

To begin with I have nothing to sell you but my services. No merchandise of any kind, and I have no connections with any other Engineering Company, Foundry, Machine Shop, Boiler or Tank Works.

There are no commissions coming to me from any source when I serve you, and hence you are able to buy your apparatus and materials without these costly complications.

There is no piece of apparatus or device made by anyone in the United States for this work, but what I will design one for you as good if not better, and probably to cost you half the price of the other, hence by making use of me as your Engineer, you are able to get what you want, have it made in any part of the country you please, and get competitive bids on it that really are competitive, and so be able to purchase at a low price.

My entire charge will be more than saved on the cost of your apparatus alone.

I already have over $2,000 worth of stock drawings on Phenol apparatus alone. I have plant layouts, building plans, foundation plans, pipe arrangements, power installations and

similar drawings for plants arranged in many different ways running from ¼ ton per day capacity to 5 tons per day capacity, and costing for the apparatus alone, from $8,000 to $40,000 each.

In the apparatus, I have designs for every conceivable kind of apparatus that can be thought of for each stage of the work and from which you can make your choice.

The variations are due to difference in cost, difference in sheet metal over cast metal, difference in open and closed patterns, heating by direct fire, direct steam, hot oil circulation, hot oil bath, indirect steam, etc., movement of the fluids by centrifugal pumps, rotary pumps, belt pumps, single steam pumps, duplex steam pumps and blow cases.

Apparatus is discharged by outlets in bottom, by syphon discharge, air pressure and Carbonic Acid gas pressure.

Tanks are steel or wood and lead lined or not as wanted.

Stills are heated for operation in various ways, and condensers are spiral coils, jacketed tubes, or chamber condensers and are built of wrought iron, cast iron, sheet steel, cast or sheet nickel, are glass enameled, or galvanized, or put up in various other ways.

Filtering operations are conducted by filter-presses, nuges, or by settling as the case may be.

Disposal of cake is by carts, trams, conveyors or by automatic methods.

The rectification of Benzol is effected in the most approved manner by fractional distillation.

Other numerous variations in the apparatus are provided for, to meet the limitations of expense that may be desired, or to meet the most complete requirements that can be devised regardless of expense, or to obviate all wastes or dangers, or to be the easiest and simplest methods that will really do the work.

All these various ways and plans have been required during the past year, to meet the requirements of the different Clients and inquiries, and new and modified forms of apparatus are continually being devised in anticipation of some future requirement.

From this you can see that there is no such thing as a stereotyped form or plan for a Phenol plant, any more than there is for the building of a home.

The plans will all depend on the amount of money that is intended to be spent on the plant, and the other numerous factors that will govern the methods that are to be employed.

The Engineering work then consists in submitting to you a large line of detailed apparatus to select from, and then design-

ing such new as may be required, or changing over such stock designs as will fit the occasion. Also in arranging the units for you in a progressive and proper correlation, in laying all this work out for you quickly and completely, and in providing the necessary shop drawings worked out in the minutest detail, so that you can ask any Foundry, Machine Shop, or Boiler Maker to name you a price on it.

I am also at your service to assist you all that you may wish in the buying of the units, but as every man believes he is capable of doing his own buying and generally he is, then I try to prepare you to do it in the best manner possible, rather than to insist on doing it for you myself.

I can direct you to numerous concerns who are fitted to do the work. Frequently I already have their figures. This does not mean you are in any way obligated to deal with them if you can do better elsewhere, their prices, however, may be indicative and thus be of help to you.

I furnish you all the Chemistry, both practical and the theory, hundreds of sheets of typewriting as we go along and post you on every step.

I teach your employees all the necessary steps and supervise the work from start to finish.

I direct you to the various sources of raw materials, and if necessary to the proper people where you can dispose of your product.

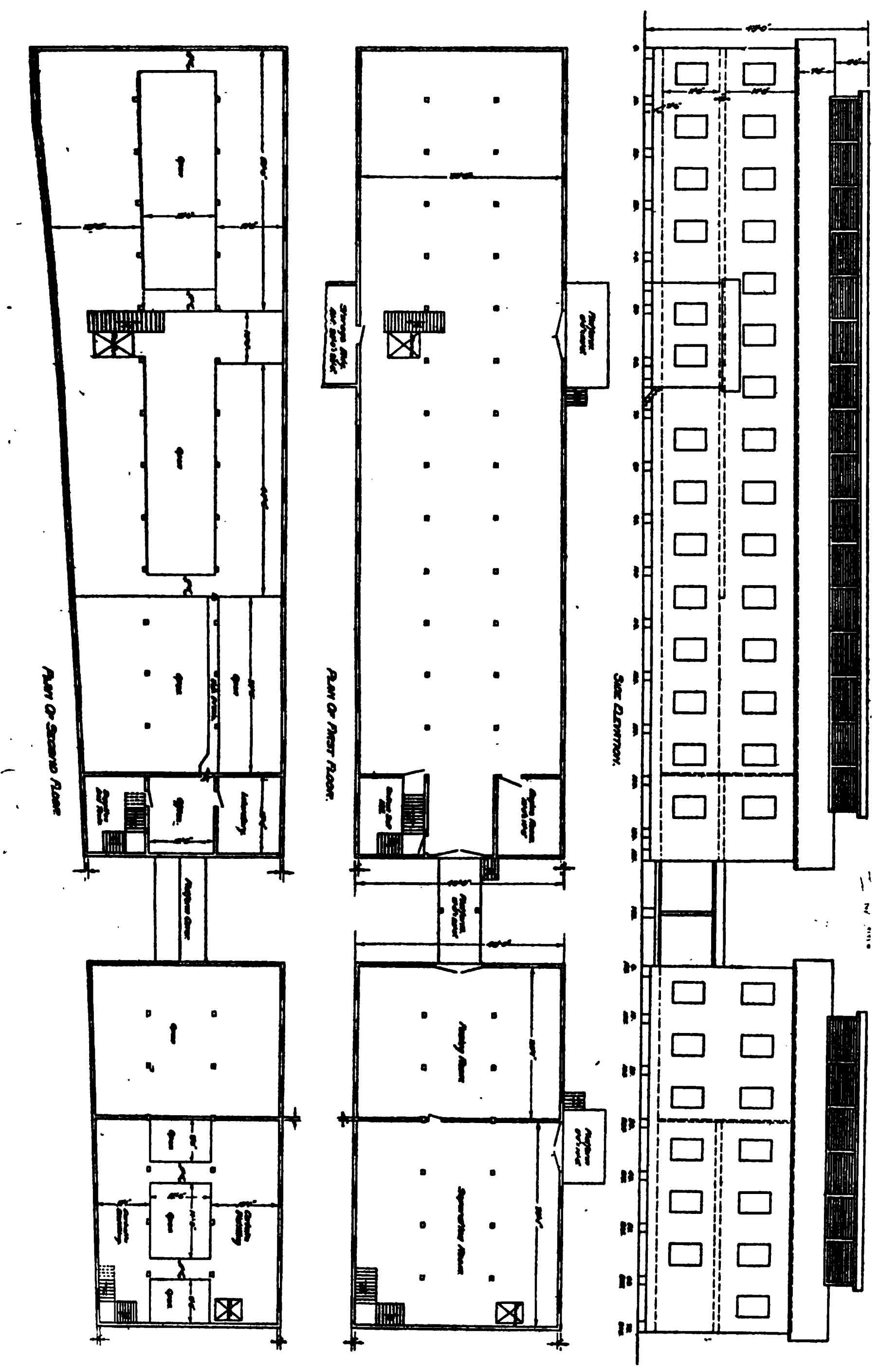
You will receive in all over $2,500 worth of drawings and drafting work and all this can be done in a very few weeks time.

While I shall not be able to be in personal attendance on the work all the time that your plant is going up, I expect to be there as often as necessary and stay as long as may be required, but as I have other plants that also require my services at the same time, you would be obliged to have someone in charge of the actual erection work, and I would keep them supplied with minute instructions ahead of time all the while, and the drawings would be ready as fast as they were needed.

I would start up the plant for you and not leave it until a competent man had been properly broken in and was capable of running it.

The Chemistry of Synthetic Phenol is quite intricate, but all this is made very clear, and every side reaction is carried out, and the theory worked out at every stage of the process for comparison with the actual results.

With the assistance then that I can give you, it places you



**BOTH FLOOR PLANS AND SIDE ELEVATION, FOR TWO TON PHENOL PLANT WITHOUT BENZOL RECTIFIER.**

**Buildings 245 ft. long (over all), 40 ft. wide and 29½ ft. high on sides.**

in a few days time in a position in which you are as well posted on the whole subject, both chemical and mechanical, as anyone can be after a year's steady application at the work.

It gives you all this information in time and upon which you are able to intelligently make your purchases of equipment, and it gives you a feeling of real confidence in the project that you cannot have where you pay a lump sum for the apparatus, the process and its setting up, and know very little about it all until you are called upon to pay the bill and take it over.

This is the real function of a Chemical Engineer and not that of mixing an apparatus manufacturing commercial proposition up with professional work. In specializing on one or two subjects thus, the Engineering work should then have some real merit.

## CHARGES AND TERMS.

The charges for the writer's services as Chemical Engineer are based on the capacity of the Phenol plant.

All the information that is required on every part of the work will be furnished you.

You will be directed to the sources of supply for the raw materials and help given you in locating suitable manufacturers to build your apparatus.

Building plans and suggestions will be submitted to you on all the construction work.

All the units and their arrangement will be properly designed beforehand.

Instruction will be given your employees in the various steps of the process, and you will receive such advice as you may need in preparing and marketing the product.

For this entire service the charge is $2,500 per ton daily capacity of the plant and that amount as a minimum charge.

This money is paid as follows:

$500 Cash upon delivery to you of the details of process and manufacture, and a collection of over 100 general drawings that will serve to illustrate the apparatus and its proper operation. This set of drawings will represent over $2,000 alone.

The drawings (each 26x36 inches), and typewriting, are handsomely bound in book form, gold lettered and suitable for preservation.

A contract is also entered into, embodying all essential

oints and covering a period of two years.

Opportunity is then given the Client to thoroughly familiarze himself on every point, and explanations are given of any obscure portions.

It is supposed that during this time the Client will produce some Phenol himself in the Laboratory according to the instructions and without any assistance whatever from the Engineer, and thus settle definitely as to whether the process is correct or not. This will then leave no occasion for asking for guarantees, bonds, or references to other Phenol plants that the Engineer may at the same time be also associated with.

If the process then is as it has been represented, and you have submitted the drawings to competent mechanical advisors who approve of them, and you are still disposed to continue the project, then the Engineer is to receive a drawing account of from $50 to $75 per week, according to distance, which shall continue until the plant is in operation and has been capable of producing for 30 days; then the balance of the $2,500 (less all amounts so far paid) is to be paid.

If after such study of the project as outlined above, you should for any reason whatever decide the project not advisable, you are at liberty to withdraw without further payments or obligations if you wish to do so, except the obligation, that if at any time during the ensuing two years you should take the project up again, that it reinstates the contract just where it was left off, whether the completion of the work is done by the writer or by someone else.

In this event it has cost you merely the $500 to become thoroughly posted on the whole subject, but as there has virtually been delivered over to you all the information on receipt of the $500, it is considered that the balance of $2,000 is still due, if you eventually go into the business, whether with the same or with a different Engineer.

If the project, however, is carried out, the writer is at your service during the entire two years for consultation and advice without further charge, and is to supply you all Engineering details for plant enlargement whenever they are wanted, and likewise to receive a pro-rata fee on any increased capacity whenever it is actually attained.

As the writer is putting in work of this kind all the time, you have the opportunity of thus learning all the newer methods as they are applied and can keep abreast of everything that may thus be of value.

It would be impossible to do the work at the above price

except that now an immense stock of drawings have accumulated to draw from, and thus it is possible to work very rapidly.

The amount of the fee will be easily saved in the purchase of your apparatus alone, and you could not possibly install the plant yourself for the same figures that it can be supervised for you, besides the work can thus be done in about one-third the time that you would take in the usual way.

About 60 days is required to install a one-ton plant after the buildings and power are ready for it.

## CONSULTING WORK ON SYNTHETIC PHENOL.

While it is the intention of the writer as Engineer to devote the most of his time during the present high price of chemicals to the designing and installation of new Synthetic Phenol and Beta Naphthol plants, yet where opportunity is offered of consultation and remodeling of present plants, he will be glad to co-operate with the owners to the changing of the older methods over into the more modern ways, and charges will be made with due regard to the individual case.

On new work it is advisable to turn over the entire supervision and obtain the whole of the data from the same source.

The results then will depend on the Engineer alone, and in that event he is perfectly willing to assume the whole responsibility.

No commissions can be given to other Engineers, or any division of the regular fee, and the price is the same to everybody.

The writer has probably done as much work in the past year on this one subject as all the other engineering firms collectively, who are only now and then taking it up along with their other numerous chemical installations.

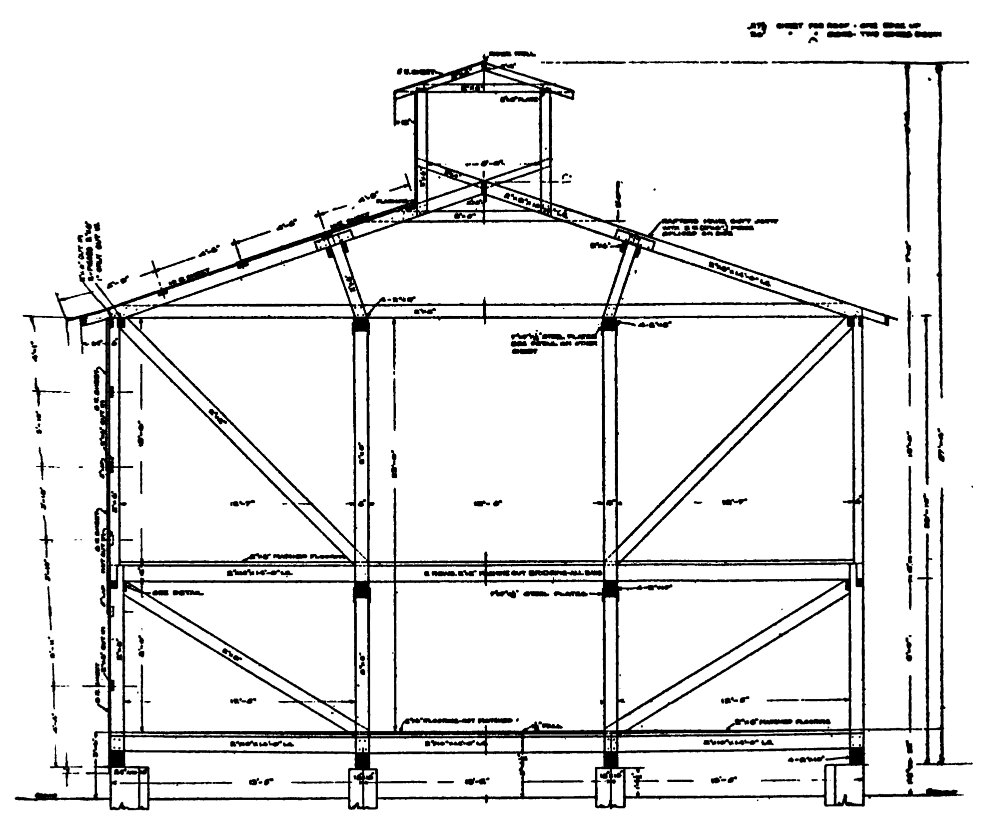
Frequently apparatus designed expecially for Phenol work is also suitable for other chemical processes, such as a proper sulphonation kettle also being suitable for a nitrating kettle, carbolic stills suitable also for many other purposes, caustic soda autoclaves also adaptable to other autoclave use, and so prices have been placed on some of the drawings shown in this pamphlet in case they are desired separately.

The prices named include complete details for every part, full information relative to the operation, names of various makers who are fitted to build the work, with their prices on both the apparatus and the necessary patterns.

If you are putting in some chemical process, you will find that a vast amount of time is generally lost when you start out to purchase the larger apparatus units.

Only foundries familiar with sweep or loam work are able to properly produce large cast iron pots or kettles, and large lathes or boring mills are required for machining the larger surfaces.

Unless you are able to use the stock apparatus from the few



CROSS SECTION OF BUILDING, SUGGESTING FRAME CONSTRUCTION TO BE COVERED WITH CORRUGATED GALVANIZED IRON.

While it is not the intention of the Engineer to become the Architect for the building work, yet a dozen or more suggestive lateral and transverse sections, as well as other building plans are supplied, to assist in quickly disposing of this work.

apparatus building companies, you must furnish your own drawings or pay some one the cost for having them made.

Then locating the proper builder who has the necessary facilities and who can quote you a reasonable price, is a task requiring much time and patience, and in the end perhaps you do not receive all that you might have been able to get for the money, if you had known better just where to look and what was really wanted.

In furnishing drawings of any of the apparatus shown here, the price includes not only the drawings, but the names of many firms who have already submitted bids on the work, as well as their various prices, time of delivery, and everything ready for you to merely place your order.

Thus the cost of the drawings are more than saved you by your being able to select from competitive prices, and in having estimates that were based on clear details, and devoid of any further drafting-room expense.

The manufacturer is saved all this work, he consequently quotes a lower price, and the cost of the work, plus the cost of these drawings, is still much below any figure that you can obtain anywhere yourself, and the work throughout will be based on experience and a thorough knowledge of the requirements.

All of the apparatus shown in this pamphlet has been specially designed by the writer, either for Phenol use or for other chemical processes. No attempts have been made to follow or imitate other Engineers' or Manufacturers' designs.

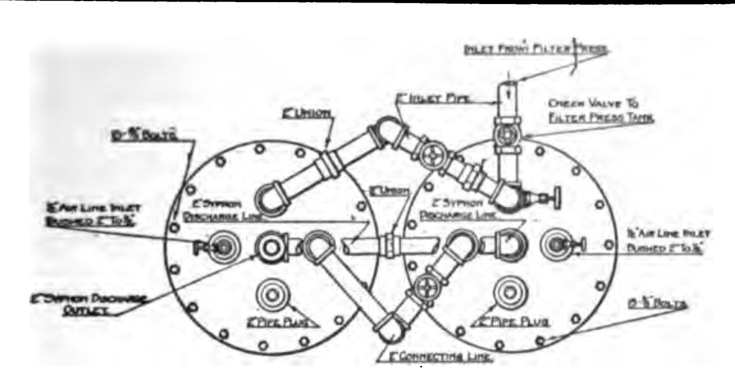
Every Machine Shop, Foundry or Tank maker who has facilities for making any of the apparatus shown, is requested to communicate with the writer, if they care to submit estimates on any part of this work.

Blue prints will then be sent for price, and your figures will be submitted to any clients who contemplate putting in any of these units.

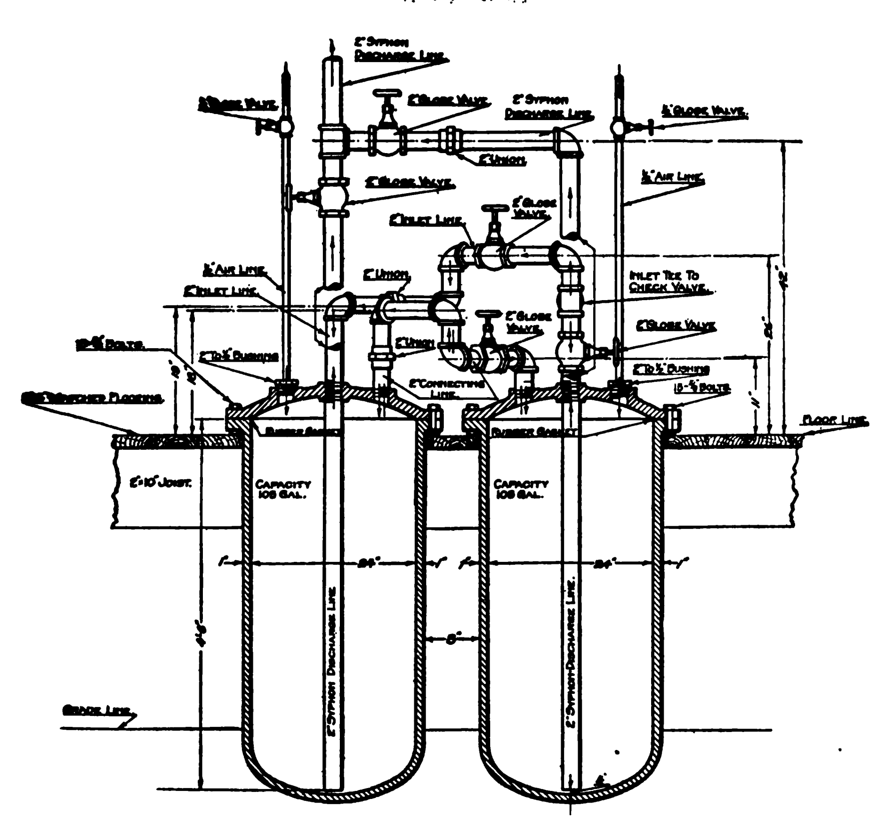
Frequently your locality may be near that of the prospective client and a material freight saving can thus be made as well as an earlier delivery.

Well equipped machine shops at a considerable distance from New York City are especially invited to submit prices on the larger pieces, because most of the plants doing this work within 50 miles of New York City, are crowded with business and frequently unable to handle any more of it for months to come.

The Engineer.




Plan Of Twin Blow Cases Or Eggs.




Section Elevation Of Twin Blow Cases Or Eggs.
Cast Iron

## CAST IRON TWIN BLOW-CASES OR EGGS (MONTEJUS).

**Capacity 105 gal. each, 24 in. diameter, 54 inches deep, 5 openings in cover, weight 1,500 lbs. each. Can be built in cast iron for $90.00, or in ¼ in. sheet steel welded (weighing 150 lbs.) for $43.00 each.**

**3 sheets of detail drawings of blow-case and pipe connections, with names and prices of various makers who have submitted bids. Price, $30.00.**

# ONE TON SYNTHETIC PHENOL PLANT, EITHER ONE OR TWO LEVEL PROCESS, FOR ONE TON IN ONE SHIFT OF TEN HOURS.

The following items would constitute the necessary apparatus for a very complete and up-to-date installation, including a liberal capacity at every step and of the most approved type throughout:

† 1 Benzol rectifier, 30" cast iron column, 28 chambers, and 1,800 gal. sheet steel still, with a capacity of 50 gal. per hour. Total height 43 ft., total weight 13 tons. Used for fractionating the benzol.

*† 1 Outside benzol storage tank, to bury under ground, sheet steel and about 1,000 gal., empties by carbonic acid pressure.

*† 1 Concentrated sulphuric acid storage tank outside, to set in concrete cradle, sheet steel and about 1,000 gal., empties by gravity discharge.

*† 1 Chamber acid storage tank outside, to set in concrete cradle, sheet steel and about 1,000 gal., empties by gravity discharge.

* 1 Milk of lime tank, ¼" sheet steel, with agitator, closed top, 4 ft. diam. x 4½ ft. deep, 420 gal., air pressure discharge.

2 Sheet steel measuring tanks or eggs, with gauge glasses, closed tops, 32" diam. x 36" deep, 125 gal. each, syphon discharge.

† 1 Sheet steel hot oil blow-case, welded, ¼" shell, 5/16" cover, 105 gal. syphon discharge, weight 150 lbs.

* 4 Cast iron sulphonating kettles with agitators and double jackets, each 320 gal. capacity, weight of each 8,500 lbs.

* 4 Reflux condenser sheet steel tanks, each with 72 ft. of 2" condensing pipe coil; Tanks 2 ft. diam. x 5 ft. deep.

4 Soft seat safety valves for vapor, low pressure.

† 1 Lead lined, 300 gal. wood tank for the sulphonate.

* 4 Neutralizing tanks, 3" cypress, 8 ft. diam. x 4½ ft. deep, weight of each 2,400 lbs.

* 4 Agitators for same, with T. & L. pulleys, gears, pillow blocks, etc.

*‡ 3 Wash filter presses, 36 chambers, 30" x 1¼" plates, safety valve and trough, weight of each 11,600 lbs.

†‡ 3 Dummy plates for filter presses, weight each 325 lbs.

3 Sets filter cloths.

‡ 3 Pair twin blow-cases for filter presses, ¼" sheet steel, welded, 5/16" cover, 105 gal. each, syphon discharge, weight of the six 900 lbs.

‡ 4 Duplex steam pumps 4½" x 2¾" x 4" for filter presses.

*†‡ 3 Wash-water tanks, 3" cypress, 8 ft. diam. x 7 ft. deep, weight of each 3,400 lbs.

* 2 Soda tanks, 3" cypress, 8 ft. diam. x 7 ft. deep, weight of each 3,400 lbs.

* 2 Agitators for same, with T. & L. pulleys, gears, pillow blocks, etc.

* 4 Concentrating tanks, 3" cypress, 8 ft. diam. x 4 ft. deep, weight of each 2,000 lbs.

* 2 Round cast iron crystallizing pans with steam jackets and stirring device, T. & L. pulleys, gears, adjustments and self discharging, weight of each 12,000 lbs.

† 1 No. 4 steel burr mill for grinding sodium salt crystals, weight 320 lbs.

* 2 Cast steel autoclaves for fusing, to set in brick, closed top, agitator, self discharging, 32" inside diam. by 56" deep, 2" walls, weight of each 6,000 lbs.

2 Cauldron plates for autoclaves.

2 Brick settings for autoclaves.

† 1 Dissolving tank with agitator, sheet steel and cast iron, 4 ft. diam. x 8 ft. deep, closed top, jacketed bottom.

*‡ 2 Sheet steel, conical bottom separation tanks, 5½ ft. diam. by 12 ft. deep, with agitator, closed top, gauge glasses, air, acid and steam coils, weight of each 4,000 lbs.

‡ 4 sets of 1½" gauge glasses each 3 ft. long, for separation tank.

* 2 Agitators for separation tank, with T. & L. pulleys, gears, pillow blocks, etc.

‡ 2 Sheet steel blow-cases for liquid carbolic, ¼" shell, 5/16" cover, 105 gal. each, syphon discharge, weight of each 150 lbs.

1 Square, lead lined, chamber acid mixing tank, 4½ ft. x 4½ ft. x 4½ ft., 680 gal.

1 Cast iron blow-case for chamber acid, 105 gal., 2 ft. diam. inside by 4½ ft. deep, weight 1,500 lbs.

†* 1 Washer for carbolic, sheet steel, closed top, agitator, 318 gal., 3 ft. diam. x 6 ft. deep, air pressure discharge.

†‡ 2 Separation cylinders 3/16" sheet steel, closed top, reservoir and gauge-glass below, 245 gal., 20" diam. x 15 ft. long.

* 3 150 gal. cast iron, oil jacketed, carbolic stills, with head and gooseneck, weight of each 6,000 lbs.

* 3 Twin tank condensers for carbolic stills, each tank jacketed, 12 sheet steel tanks in all.

*† 1 Oil heater for stills, either cast pot or sheet steel tank.

† 1 Brick setting for oil heater.

† 1 Duplex steam pump for oil.

3 Oil burners.

† 1 Caustic solution, vapor recovery tank, sheet steel, 750 gal., 4 ft. diam. x 8 ft. deep, closed top.

1 Air compressor and tanks.

† 1 24" square steam plate.

†‡ 14 Pipe-leg tank benches.

†‡ 2 Metal tanks for crystalline carbolic distillate.

†‡ 3 Metal tanks for watery carbolic distillate.

† 1 Enameled, crystal carbolic storage tank.

* 2 Platform scales for weighing stock.

† 1 Metal tank and agitator, for disposing of calcium sulphate cake, closed top if fluid disposal is wanted.

† 1 Metal tank and agitator for handling calcium carbonate cake, closed top and for air, unless solid cake is handled instead.

† 4 Reynolds shop trucks.

†‡ 50 Galvanized stock cans to hold 100 lbs. dry material each.

* Thermometers, gauges, valves and tools.

Piping and installation labor.

Total about ........................................ $22,000.00

No Buildings, Power, Shafting, or Belts, are included in the above estimate, as it is only for the chemical apparatus, piping, fittings, and necessary labor for installing it.

The total cost for the necessary apparatus and installing it, after making use of the economies indicated above, would be about $17,500, or a reduction of $4,500, if rigid economy in installation was practiced.

* All items marked thus can be provided for in several ways, among which are much cheaper means if they are required.

† Items marked thus can be eliminated entirely if it is necessary to curtail the expense materially.

‡ This indicates that a less number of the items can be used than mentioned if it is a case of imperative necessity.

## TABLE FOR CONVERTING DEGREES OF THE CENTIGRADE THERMOMETER INTO DEGREES OF FAHRENHEIT'S SCALE

| Centigrade | Fahrenheit | Centigrade | Fahrenheit | Centigrade | Fahrenheit |
|---|---|---|---|---|---|
| —90° | 130° | 40° | 104° | 170° | 338° |
| 85 | 121 | 45 | 113 | 175 | 348 |
| 80 | 112 | 50 | 122 | 180 | 356 |
| 75 | 103 | 55 | 131 | 185 | 365 |
| 70 | 94 | 60 | 140 | 190 | 374 |
| 65 | 85 | 65 | 149 | 195 | 383 |
| 60 | 76 | 70 | 158 | 200 | 392 |
| 55 | 67 | 75 | 167 | 205 | 401 |
| 50 | 58 | 80 | 176 | 210 | 410 |
| 45 | 49 | 85 | 185 | 215 | 419 |
| 40 | 40 | 90 | 194 | 220 | 428 |
| 35 | 31 | 95 | 203 | 225 | 437 |
| 30 | 22 | 100 | 212 | 230 | 446 |
| 25 | 13 | 105 | 221 | 235 | 455 |
| 20 | —4 | 110 | 230 | 240 | 464 |
| 15 | +5 | 115 | 239 | 245 | 473 |
| 10 | 14 | 120 | 248 | 250 | 482 |
| —5 | 23 | 125 | 257 | 255 | 491 |
| 0 | 32 | 130 | 266 | 260 | 500 |
| +5 | 41 | 135 | 275 | 265 | 509 |
| 10 | 50 | 140 | 284 | 270 | 518 |
| 15 | 59 | 145 | 293 | 275 | 527 |
| 20 | 68 | 150 | 302 | 280 | 536 |
| 25 | 77 | 155 | 311 | 285 | 545 |
| 30 | 86 | 160 | 320 | 290 | 554 |
| 35 | 95 | 165 | 329 | 295 | 563 |

To convert °F to °C $\frac{(°F - 32) \times 5}{9} = °C$

To convert °C to °F $\frac{°C \times 9}{5} + 32° = °F$

## TWO TON SYNTHETIC PHENOL PLANT, EITHER ONE OR TWO LEVEL PROCESS, FOR TWO TONS IN ONE SHIFT OF TEN HOURS.

To the cost of a one ton plant add:

4 Sulphonating kettles.
4 Reflux condensers.
4 Safety valves.
3 Filter presses.
3 Dummy plates.
3 Sets filter cloths.
3 Pair blow-cases.
3 Duplex pumps for presses.
3 Wash-water tanks.
2 Soda tanks.
2 Agitators for same.
4 Concentrating tanks.
2 Crystallizing pans.
1 Grinding mill.
2 Autoclaves.
2 Cauldron plates for same.
2 Brick settings.
2 Separation tanks.
4 Sets of gauge-glasses.
2 Agitators for separation tank.
2 Separation cylinders.
3 Carbolic stills.
3 Twin condensers.
2 Oil burners.
9 Tank benches.
5 Metal tanks for carbolic distillate.
Piping, valves, labor, etc.

| | |
|---|---|
| | $14,000.00 |
| Cost of one Ton Plant | $22,000.00 |
| Cost of two Ton Plant | $36,000.00 |

The same proportionate reduction in cost can be made in the two ton plant as is made in the one ton plant.

Either the one ton or the two ton plants have a reserve capacity of 25% additional, when full capacity of each unit is utilized.

Also two shifts of the entire apparatus can be run in 24 hours if necessary and thus double the production at any time, with the existing equipment.

The cost of all the larger items enumerated above has advanced from 25% to 100% within the past 12 months and will probably advance still further, so that allowances should be made for these changes in figures as the year advances.

All manufacturers who can build chemical apparatus are crowded with orders and so their prices have been unduly raised, which explains the difference in costs today and 12 months ago.

Two 2 story buildings are necessary for a 2,000 lb. plant, 1 building 40 ft. wide and 150 ft. long, the other 40 ft. wide and 70 ft. long. The walls should be 11 ft. high on lower level, and 14 ft. high on upper level.

**For a one story layout there should be 1 building, 240 ft. long (or two buildings each 120 ft. long) and 42 ft. wide and a second building 100 ft. long and 42 ft. wide with inside walls at least 15 ft. high.**

**Either of these arrangements then allow of sufficient room to double the plant's capacity at any time, by setting in the space allowed, the necessary additional apparatus.**

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## International Atomic Weights, 1918.

| Element | Symbol | O=16. |
|---|---|---|
| Aluminium | Al | 27·1 |
| Antimony | Sb | 120·2 |
| Argon | A | 39·88 |
| Arsenic | As | 74·96 |
| Barium | Ba | 137·37 |
| Bismuth | Bi | 208·0 |
| Boron | B | 11·0 |
| Bromine | Br | 79·92 |
| Cadmium | Cd | 112·40 |
| Cæsium | Cs | 132·81 |
| Calcium | Ca | 40·07 |
| Carbon | C | 12·00 |
| Cerium | Ce | 140·25 |
| Chlorine | Cl | 35·46 |
| Chromium | Cr | 52·0 |
| Cobalt | Co | 58·97 |
| Columbium | Cb | 93·5 |
| Copper | Cu | 63·57 |
| Dysprosium | Dy | 162·5 |
| Erbium | Er | 167·7 |
| Europium | Eu | 152·0 |
| Fluorine | F | 19·0 |
| Gadolinium | Gd | 157·3 |
| Gallium | Ga | 69·9 |
| Germanium | Ge | 72·5 |
| Glucinum | Gl | 9·1 |
| Gold | Au | 197·2 |
| Helium | He | 3·99 |
| Holmium | Ho | 163·5 |
| Hydrogen | H | 1·008 |
| Indium | In | 114·8 |
| Iodine | I | 126·92 |
| Iridium | Ir | 193·1 |
| Iron | Fe | 55·84 |
| Krypton | Kr | 82·92 |
| Lanthanum | La | 139·0 |
| Lead | Pb | 207·10 |
| Lithium | Li | 6·94 |
| Lutecium | Lu | 174·0 |
| Magnesium | Mg | 24·32 |
| Manganese | Mn | 54·93 |
| Mercury | Hg | 200·6 |
| Molybdenum | Mo | 96·0 |
| Neodymium | Nd | 144·3 |
| Neon | Ne | 20·2 |
| Nickel | Ni | 58·68 |
| Niton (radium emanation) | Nt | 222·4 |
| Nitrogen | N | 14·01 |
| Osmium | Os | 190·9 |
| Oxygen | O | 16·00 |
| Palladium | Pd | 106·7 |
| Phosphorus | P | 31·04 |
| Platinum | Pt | 195·2 |
| Potassium | K | 39·10 |
| Praseodymium | Pr | 140·6 |
| Radium | Ra | 226·4 |
| Rhodium | Rh | 102·9 |
| Rubidium | Rb | 85·45 |
| Ruthenium | Ru | 101·7 |
| Samarium | Sa | 150·4 |
| Scandium | Sc | 44·1 |
| Selenium | Se | 79·2 |
| Silicon | Si | 28·3 |
| Silver | Ag | 107·88 |
| Sodium | Na | 23·00 |
| Strontium | Sr | 87·63 |
| Sulphur | S | 32·07 |
| Tantalum | Ta | 181·5 |
| Tellurium | Te | 127·5 |
| Terbium | Tb | 159·2 |
| Thallium | Tl | 204·0 |
| Thorium | Th | 232·4 |
| Thulium | Tm | 168·5 |
| Tin | Sn | 119·0 |
| Titanium | Ti | 48·1 |
| Tungsten | W | 184·0 |
| Uranium | U | 238·5 |
| Vanadium | V | 51·0 |
| Xenon | Xe | 130·2 |
| Ytterbium (Neoytterbium) | Yb | 172·0 |
| Yttrium | Yt | 89 0 |
| Zinc | Zn | 65·37 |
| Zirconium | Zr | 90·6 |

## Comparative Hydrometer Scale, Sp. Gr., Twaddell, and Baumé, at 12·5° C.

| Twaddell. | Baumé. | Specific Gravity. | Twaddell. | Baume. | Specific Gravity. |
|---|---|---|---|---|---|
| 0 | 0 | 1·000 | 54 | 30·6 | 1·270 |
| 1 | 0·7 | 1·005 | 55 | 31·1 | 1·275 |
| 2 | 1·4 | 1·010 | 56 | 31·5 | 1·280 |
| 3 | 2·1 | 1·015 | 57 | 32·0 | 1·285 |
| 4 | 2·7 | 1·020 | 58 | 32·4 | 1·290 |
| 5 | 3·4 | 1·025 | 59 | 32·8 | 1·295 |
| 6 | 4·1 | 1·030 | 60 | 33·3 | 1·300 |
| 7 | 4·7 | 1·035 | 61 | 33·7 | 1·305 |
| 8 | 5·4 | 1·040 | 62 | 34·2 | 1·310 |
| 9 | 6·0 | 1·045 | 63 | 34·6 | 1·315 |
| 10 | 6·7 | 1·050 | 64 | 35·0 | 1·320 |
| 11 | 7·4 | 1·055 | 65 | 35·4 | 1·325 |
| 12 | 8·0 | 1·060 | 66 | 35·8 | 1·330 |
| 13 | 8·7 | 1·065 | 67 | 36·2 | 1·335 |
| 14 | 9·4 | 1·070 | 68 | 36·6 | 1·340 |
| 15 | 10·0 | 1·075 | 69 | 37·0 | 1·345 |
| 16 | 10·6 | 1·080 | 70 | 37·4 | 1·350 |
| 17 | 11·2 | 1·085 | 71 | 37·8 | 1·355 |
| 18 | 11·9 | 1·090 | 72 | 38·2 | 1·360 |
| 19 | 12·4 | 1·095 | 73 | 38·6 | 1·365 |
| 20 | 13·0 | 1·100 | 74 | 39·0 | 1·370 |
| 21 | 13·6 | 1·105 | 75 | 39·4 | 1·375 |
| 22 | 14·2 | 1·110 | 76 | 39·8 | 1·380 |
| 23 | 14·9 | 1·115 | 77 | 40·1 | 1·385 |
| 24 | 15·4 | 1·120 | 78 | 40·5 | 1·390 |
| 25 | 16·0 | 1·125 | 79 | 40·8 | 1·395 |
| 26 | 16·5 | 1·130 | 80 | 41·2 | 1·400 |
| 27 | 17·1 | 1·135 | 81 | 41·6 | 1·405 |
| 28 | 17·7 | 1·140 | 82 | 42·0 | 1·410 |
| 29 | 18·3 | 1·145 | 83 | 42·3 | 1·415 |
| 30 | 18·8 | 1·150 | 84 | 42·7 | 1·420 |
| 31 | 19·3 | 1·155 | 85 | 43·1 | 1·425 |
| 32 | 19·8 | 1·160 | 86 | 43·4 | 1·430 |
| 33 | 20·3 | 1·165 | 87 | 43·8 | 1·435 |
| 34 | 20·9 | 1·170 | 88 | 44·1 | 1·440 |
| 35 | 21·4 | 1·175 | 89 | 44·4 | 1·445 |
| 36 | 22·0 | 1·180 | 90 | 44·8 | 1·450 |
| 37 | 22·5 | 1·185 | 91 | 45·1 | 1·455 |
| 38 | 23·0 | 1·190 | 92 | 45·4 | 1·460 |
| 39 | 23·5 | 1·195 | 93 | 45·8 | 1·465 |
| 40 | 24·0 | 1·200 | 94 | 46·1 | 1·470 |
| 41 | 24·5 | 1·205 | 95 | 46·4 | 1·475 |
| 42 | 25·0 | 1·210 | 96 | 46·8 | 1·480 |
| 43 | 25·5 | 1·215 | 97 | 47·1 | 1·485 |
| 44 | 26·0 | 1·220 | 98 | 47·4 | 1·490 |
| 45 | 26·4 | 1·225 | 99 | 47·8 | 1·495 |
| 46 | 26·9 | 1·230 | 100 | 48·1 | 1·500 |
| 47 | 27·4 | 1·235 | 101 | 48·4 | 1·505 |
| 48 | 27·9 | 1·240 | 102 | 48·7 | 1·510 |
| 49 | 28·4 | 1·245 | 103 | 49·0 | 1·515 |
| 50 | 28·8 | 1·250 | 104 | 49·4 | 1·520 |
| 51 | 29·3 | 1·255 | 105 | 49·7 | 1·525 |
| 52 | 29·7 | 1·260 | 106 | 50·0 | 1·530 |
| 53 | 30·2 | 1·265 | | | |

To convert degrees Tw. into sp. gr., multiply by 5, add 1000, and divide by 1000.

## ONE-QUARTER TON SYNTHETIC PHENOL PLANT, ONE LEVEL PROCESS, FOR ONE-QUARTER TON IN TEN HOURS.

The following items would constitute the necessary apparatus for a very complete and up to date installation, including a liberal capacity at every step and of the most approved type throughout, but without a benzol rectifying unit.

† 1 Outside benzol storage tank, to bury under ground, sheet steel and about 1,000 gal., empties by carbonic acid pressure.

† 1 Concentrated sulphuric acid storage tank outside, to set in concrete cradle, sheet steel and about 1,000 gal., empties by gravity discharge.

† 1 Chamber acid storage tank outside, to set in concrete cradle, sheet steel and about 1,000 gal., empties by gravity discharge.

* 1 Milk of lime mixing tank, ¼" sheet steel, with agitator, closed top, 4 ft. diam. by 4½ ft. deep, 420 gal., air pressure discharge.

2 Sheet steel measuring tanks or eggs with gauge glasses, closed tops, 32" diam. by 36" deep, 125 gal. each, syphon discharge.

† 1 Sheet steel, hot oil blow-case, welded, ¼" shell, 5/16" cover, 105 gal. capacity, syphon discharge, weight 150 lbs.

* 1 Cast iron sulphonating kettle with agitator and double jacket, 320 gal. capacity, weight 8,500 lbs.

* 1 Reflux condenser sheet steel tank, with 72 ft. of 2" condensing pipe coil. Tank 2' diam. by 5' deep.

1 Soft seat safety valve for vapor, low pressure.

† 1 Lead lined, 300 gal., wood tank for the sulphonate.

* 1 Neutralizing tank, 3" cypress, 8 ft. diam. by 4½ ft. deep, weight 2,400 lbs.

* 1 Agitator for same with T. & L. pulleys, gears, pillow blocks, etc.

1 Wash filter press, 24 chambers, 24" x 1¼" plates, safety valve and trough, weight 5,000 lbs.

† 1 Wash filter press, 18 chambers, 24" x 1¼" plates, safety valve and trough, weight 4,200 lbs.

†‡ 2 Dummy plates for filter presses, weigh each 200 lbs.

2 Sets filter cloths.

‡ 2 Pair twin blow-cases for filter presses, ¼" sheet steel, welded, 5/16" cover, 105 gal. capacity, syphon discharge, weight of each 150 lbs.

‡ 3 Duplex steam pumps, 4½" x 2¾" x 4", for filter presses.

*†‡ 3 Wash water tanks, 3" cypress, 8 ft. diam. by 7 ft. deep, weight of each 3,400 lbs.

* 1 Soda tank, 3" cypress, 8 ft. diam. by 7 ft. deep, weight 3,400 lbs.

* 1 Agitator for same, with T. & L. pulleys, gears, pillow blocks, etc.

* 1 Concentrating tank, 3" cypress, 8 ft. diam. by 4 ft. deep, weight 2,000 lbs.

* 1 Round cast iron crystallizing pan, with steam jacket and stirring device, T. & L. pulleys, gears, adjustments and self discharging, weight 12,000 lbs.

† 1 No. 4 steel burr mill for grinding sodium salt crystals, weight 320 lbs.

* 1 Cast steel autoclave for fusing, to set in brick, closed top, agitator, self discharging, 32" inside diameter by 56" deep, 2" walls, weight 6,000 lbs.
1 Cauldron-plate for autoclave.
1 Brick setting for autoclave.
† 1 Dissolving tank with agitator, sheet steel and cast iron, 4 ft. diam. by 8 ft. deep, closed top, jacketed bottom.
* 1 Sheet steel, conical bottom separation tank, 5½ ft. diam. by 12 ft. deep, with agitator, closed top, gauge glasses, air, acid and steam coils, weight 4,000 lbs.
‡ 2 Sets of 1½" gauge glasses, each 3 ft. long, for separation tank.
* 1 Agitator for separation tank with T. & L. pulleys, gears, pillow blocks, etc.
‡ 2 Sheet steel blow-cases for liquid carbolic, ¼" shell, 5/16" cover, 105 gal. each, syphon discharge, weight of each 150 lbs.
1 Square, lead lined, chamber acid mixing tank, 4½' x 4½' x 4½', capacity 680 gal.
1 Cast iron blow-case for chamber acid, 105 gal., 2 ft. diam. inside by 4½ ft. deep, weight 1,500 lbs.
†* 1 Washer for carbolic, sheet steel, closed top, agitator, 318 gal., 3 ft. diam. by 6 ft. deep, air pressure discharge.
† 1 Separation cylinder, 3/16" sheet steel, closed top, reservoir and gauge-glass below, 245 gal., 20 in. diam. by 15 ft. long.
* 3 Cast iron, carbolic oil jacketed stills, 150 gal. capacity each, with heads and goose-necks, weight of each 6,000 lbs.
* 3 Twin tank condensers for carbolic stills, each tank jacketed, 12 sheet steel tanks in all.
*† 1 Oil heater for stills, either cast pot or sheet steel tank.
† 1 Brick setting for oil heater.
† 1 Duplex steam-pump for oil.
2 Oil burners.
† 1 Caustic solution, vapor recovery tank, sheet steel, 750 gal., 4 ft. diam. by 8 ft. deep, closed top.
1 Air compressor and tank.
† 1 Steam plate 24" square.
†‡ 7 Pipe-leg tank benches.
†‡ 2 Metal tanks for crystalline carbolic distillate.
†‡ 3 Metal tanks for watery carbolic distillate.
† 1 Enameled crystal carbolic storage tank.
* 1 Platform scale.
† 1 Metal tank and agitator for disposing of calcium sulphate cake, closed top if fluid disposal is wanted.
† 1 Metal tank and agitator for handling calcium carbonate cake, closed top and for air, unless solid cake is handled instead.
† 1 Reynolds shop truck.
†‡ 15 Galvanized stock cans to hold 100 lbs. each of dry material, with covers.
* Thermometers, gauges, valves and tools.
Piping and installation labor.

Total about .......... $11,000.00

## SYMBOLS AND FORMULÆ

| Symbol or Formula | Name | Symbol or Formula | Name |
|---|---|---|---|
| $KF$ | Potassium fluoride | $NH_4I$ | Ammonium iodide |
| $KHCO_3$ | „ bicarbonate | $NH_4NO_3$ | „ nitrate |
| $KHSO_3$ | „ bisulphite | $(NH_4)_2SO_4$ | „ sulphate |
| $KHSO_4$ | „ bisulphate | $NO$ | Nitric oxide |
| $KI$ | „ iodide | $NO_2$ | Nitrogen dioxide |
| $KMnO_4$ | „ permanganate | $N_2O$ | Nitrous oxide |
| $KNO_2$ | „ nitrite | $N_2O_3$ | Nitrogen trioxide |
| $KNO_3$ | „ nitrate | $N_2O_4$ | „ peroxide |
| $KOH$ | „ hydroxide | $N_2O_5$ | „ pentoxide |
| $K_2CO_3$ | „ carbonate | $Na$ | Sodium |
| $K_2C_2O_4$ | „ oxalate | $NaBr$ | „ bromide |
| $K_2C_4H_4O_6$ | „ tartrate | $NaBrO_3$ | „ bromate |
| $K_2CrO_4$ | „ chromate | $NaCN$ | „ cyanide |
| $K_2Cr_2O_7$ | „ bichromate | $NaC_2H_3O_2$ | „ acetate |
| $K_2O$ | „ oxide | $NaCl$ | „ chloride |
| $K_2Pt(CN)_4$ | „ platinocyanide | $NaClO_3$ | „ chlorate |
| $K_2PtCl_6$ | „ platinochloride | $NaClO_4$ | „ perchlorate |
| $K_2S$ | „ sulphide | $NaF$ | „ fluoride |
| $K_2SO_3$ | „ sulphite | $NaHCO_3$ | „ bicarbonate |
| $K_2SO_4$ | „ sulphate | $NaHSO_3$ | „ bisulphite |
| $K_2SO_4Al_2(SO_4)_3$ | „ alum | $NaHSO_4$ | „ bisulphate |
| $K_2SiF_6$ | „ silicofluoride | $NaH_2PO_4$ | „ dihydrogen phosphate |
| $K_2SiO_3$ | „ silicate | | |
| $K_3PO_4$ | „ phosphate | $NaI$ | „ iodide |
| | | $NaMnO_4$ | „ permanganate |
| $Li$ | Lithium | $NaNH_2$ | Sodamide |
| $LiCl$ | „ chloride | $NaNO_2$ | Sodium nitrite |
| $Li_2CO_3$ | „ carbonate | $NaNO_3$ | „ nitrate |
| $Li_2SO_4$ | „ sulphate | $NaOCl$ | „ hypochlorite |
| | | $NaOH$ | „ hydroxide |
| $Mg$ | Magnesium | $NaPO_3$ | „ metaphosphate |
| $MgCO_3$ | „ carbonate | $Na_2Al_2O_4$ | „ aluminate |
| $MgCl_2$ | „ chloride | $Na_2B_4O_7$ | „ borate (borax) |
| $Mg(NO_3)_2$ | „ nitrate | $Na_2CO_3$ | „ carbonate |
| $MgO$ | „ oxide | $Na_2CrO_4$ | „ chromate |
| $Mg(OH)_2$ | „ hydroxide | $Na_2Cr_2O_7$ | „ bichromate |
| $MgSO_4$ | „ sulphate | $Na_2O$ | „ oxide |
| $Mn$ | Manganese | $Na_2O_2$ | „ peroxide |
| $MnCO_3$ | „ carbonate | $Na_2S$ | „ sulphide |
| $MnCl_2$ | „ chloride | $Na_2SO_3$ | „ sulphite |
| $MnO_2$ | „ dioxide | $Na_2SO_4$ | „ sulphate |
| $MnSO_4$ | „ sulphate | $Na_2S_2O_3$ | „ thiosulphate |
| $Mo$ | Molybdenum | $Na_2SnO_3$ | „ stannate |
| | | $Na_2WO_4$ | „ tungstate |
| $N$ | Nitrogen | $Na_3PO_4$ | „ phosphate |
| $(NH_2)_2$ | Hydrazine | $Na_4P_2O_7$ | „ pyrophosphate |
| $NH_2.OH$ | Hydroxylamine | $Ni$ | Nickel |
| $NH_3$ | Ammonia | $NiCl_2$ | „ chloride |
| $NH_4Br$ | Ammonium bromide | $NiO$ | „ oxide |
| $NH_4.CNS$ | „ thiocyanate | $NiS$ | „ sulphide |
| $NH_4Cl$ | „ chloride | $NiSO_4$ | „ sulphate |
| $NH_4ClO_3$ | „ chlorate | $Ni_2(OH)_6$ | „ hydroxide |
| $NH_4ClO_4$ | „ perchlorate | $Ni_2O_3$ | „ oxid |
| $(NH_4)_2CrO_4$ | „ chromate | | |
| $(NH_4)_2Cr_2O_7$ | „ bichromate | $O$ | Oxygen |
| $NH_4HS$ | „ hydrosulphide | $O_3$ | Ozone |
| | | $Os$ | Osmium |
| $(NH_4)_2HPO_4$ | „ hydrogen phosphate | $P$ | Phosphorus |

## SYMBOLS AND FORMULÆ

| Symbol or Formula | Name | Symbol or Formula | Name |
|---|---|---|---|
| $PCl_3$ | Phosphorus trichloride | $SiO_2$ | Silicon dioxide (silica) |
| $PCl_5$ | " pentachloride | $Sn$ | Tin |
| $POCl_3$ | " oxychloride | $SnCl_2$ | Stannous chloride |
| $P_2O_5$ | " pentoxide | $SnCl_4$ | Stannic chloride |
| $Pb$ | Lead | $SnO_2$ | Tin oxide |
| $PbCO_3$ | " carbonate | $SnS$ | Stannous sulphide |
| $Pb(C_2H_3O_2)_2$ | " acetate | $SnS_2$ | Stannic sulphide |
| $PbCl_2$ | " chloride | $Sr$ | Strontium |
| $PbCrO_4$ | " chromate | $SrCO_3$ | " carbonate |
| $PbI_2$ | " iodide | $SrCl_2$ | " chloride |
| $Pb(NO_3)_2$ | " nitrate | $Sr(NO_3)_2$ | " nitrate |
| $PbO$ | " oxide | $SrO$ | " oxide |
| $PbO_2$ | " peroxide | $Sr(OH)_2$ | " hydroxide |
| $PbS$ | " sulphide | $SrSO_4$ | " sulphate |
| $PbSO_4$ | " sulphate | | |
| $Pb_2O_3$ | " sesquioxide | $Te$ | Tellurium |
| $Pb_3O_4$ | Minium | $Ti$ | Titanium |
| $Pd$ | Palladium | $Tl$ | Thallium |
| $Pt$ | Platinum | | |
| $PtCl_4$ | " tetrachloride | $U$ | Uranium |
| $Rb$ | Rubidium | $UO_2$ | " oxide |
| $Rh$ | Rhodium | $UO_2Cl_2$ | Uranyl chloride |
| | | $UO_2(NO_3)_2$ | " nitrate |
| $S$ | Sulphur | | |
| $SO_2$ | " dioxide | $V$ | Vanadium |
| $SO_2Cl_2$ | Sulphuryl chloride | $V_2O_5$ | " pentoxide |
| $SO_3$ | Sulphur trioxide | | |
| $Sb$ | Antimony | $W$ | Tungsten |
| $SbCl_3$ | " trichloride | | |
| $SbCl_5$ | " pentachloride | $Zn$ | Zinc |
| $Sb_2S_3$ | " trisulphide | $ZnCO_3$ | " carbonate |
| $Sb_2S_5$ | " pentasulphide | $ZnCl_2$ | " chloride |
| $Se$ | Selenium | $ZnO$ | " oxide |
| $Si$ | Silicon | $Zn(OH)_2$ | " hydroxide |
| $SiC$ | " carbide | $ZnS$ | " sulphide |
| $SiCl_4$ | " tetrachloride | $ZnSO_4$ | " sulphate |
| $SiF_4$ | " tetrafluoride | $Zr$ | Zirconium |

## USEFUL DATA

1 lb. avoir. = 16 oz. = 7·000 grains = 453·59 grammes = 1·21527 lb. troy.
1 lb. troy = 12 oz. = 5760 grains = 373·242 grammes = 0·82285704 lb. avoir.
1 oz. avoir. = 437·5 grains = 28.35 grammes = 0·9114583 oz. troy.
1 cubic cent. = ·06113 cub. in. = ·282 fl. drms. = ·00176 pint = ·0352 fl. oz.
1 cubic foot = 28315·3 cc. = 6·2321 gallons = 28·3153 litres = 997·1364 fl. oz. = 49·8568 pints.
1 English gallon = ·16046 cub. ft. = 277·274 cub. in. = 4·54356 litres.
1 cubic inch = 16·386 cc. = 0·577 fl. oz. = ·0164 litre = ·02885 pint.
1 litre = ·035316 cub. ft. = ·220096 gallon = 61·0270 cub. in. = 1·1761 pint.
1 fl. oz. = 28·396 cc. = 1·7329 cub. in.
1 pint = 567·919 cc. = ·020057 cub. ft. = 34·659 cub. in. = ·567920 litre.
1 gramme = ·002204 lb. = ·03527 oz. = 15·432348 grains.
Per cent. of tar × 2 = gallons per ton approximately.
1 per cent. nitrogen in fuel = 105 lbs. ammonium sulphate per ton (theoretical).

## Table of Percentage of Sulphuric Acid (*Lunge* and *Isler*).

| Specific Gravity at $\frac{15°}{4°}$. | Degree Baumé. | Percentage $H_2SO_4$. | Specific Gravity at $\frac{15°}{4°}$. | Degree Baumé. | Percentage $H_2SO_4$. |
|---|---|---|---|---|---|
| 1·000 | 0 | 0·09 | 1·560 | 51·8 | 65·08 |
| 1·010 | 1·4 | 1·57 | 1·570 | 52·4 | 65·90 |
| 1·020 | 2·7 | 3·03 | 1·580 | 53·0 | 66·71 |
| 1·030 | 4·1 | 4 49 | 1·590 | 53·6 | 67·59 |
| 1·040 | 5·4 | 5·96 | 1·600 | 54·1 | 68·51 |
| 1·050 | 6·7 | 7·37 | 1·610 | 54·7 | 69·43 |
| 1·060 | 8·0 | 8·77 | 1·620 | 55·2 | 70·32 |
| 1·070 | 9·4 | 10·19 | 1·630 | 55·8 | 71·16 |
| 1·080 | 10·6 | 11·60 | 1·640 | 56·3 | 71·99 |
| 1·090 | 11·9 | 12·99 | 1·650 | 56·9 | 72·82 |
| 1·100 | 13·0 | 14·35 | 1·660 | 57·4 | 73·64 |
| 1·110 | 14·2 | 15·71 | 1·670 | 57·9 | 74·51 |
| 1·120 | 15·4 | 17·01 | 1·680 | 58·4 | 75·42 |
| 1·130 | 16·5 | 18·31 | 1·690 | 58·9 | 76·30 |
| 1·140 | 17·7 | 19·61 | 1·700 | 59·5 | 77·17 |
| 1·150 | 18·8 | 20·91 | 1·710 | 60·0 | 78·04 |
| 1·160 | 19·8 | 22·19 | 1·720 | 60·4 | 78·92 |
| 1·170 | 20·9 | 23·47 | 1·730 | 60·9 | 79·80 |
| 1·180 | 22·0 | 24·76 | 1·740 | 61·4 | 80·68 |
| 1·190 | 23·0 | 26·04 | 1·750 | 61·8 | 81·56 |
| 1·200 | 24·0 | 27·32 | 1·760 | 62·3 | 82·44 |
| 1·210 | 25·0 | 28·58 | 1·770 | 62·8 | 83·32 |
| 1·220 | 26·0 | 29·84 | 1·780 | 63·2 | 84·50 |
| 1·230 | 26·9 | 31·11 | 1·790 | 63·7 | 85·70 |
| 1·240 | 27·9 | 32·28 | 1·800 | 64·2 | 86·90 |
| 1·250 | 28·8 | 33·43 | 1·810 | 64·6 | 88·30 |
| 1·260 | 29·7 | 34·57 | 1·820 | 65·0 | 90·05 |
| 1·270 | 30·6 | 35·71 | 1·821 | ... | 90·20 |
| 1·280 | 31·5 | 36·87 | 1·822 | 65·1 | 90·40 |
| 1·290 | 32·4 | 38·03 | 1·823 | ... | 90·60 |
| 1·300 | 33·3 | 39·19 | 1·824 | 65·2 | 90·80 |
| 1 310 | 34·2 | 40·35 | 1·825 | ... | 91·00 |
| 1·320 | 35·0 | 41·50 | 1·826 | 65·3 | 91·25 |
| 1·330 | 35·8 | 42·66 | 1 827 | ... | 91·50 |
| 1·340 | 36·6 | 43·74 | 1·828 | 65·4 | 91·70 |
| 1·350 | 37·4 | 44·82 | 1·829 | ... | 91·90 |
| 1·360 | 38·2 | 45·88 | 1·830 | ... | 92·10 |
| 1·370 | 39·0 | 46·94 | 1·831 | 65·5 | 92·30 |
| 1·380 | 39·8 | 48·00 | 1·832 | ... | 92·52 |
| 1·390 | 40·5 | 49·06 | 1·833 | 65·6 | 92·75 |
| 1·400 | 41·2 | 50·11 | 1·834 | ... | 93·05 |
| 1·410 | 42·0 | 51·15 | 1·835 | 65·7 | 93·43 |
| 1·420 | 42·7 | 52·15 | 1 836 | ... | 93·80 |
| 1·430 | 43·4 | 53·11 | 1·837 | ... | 94·20 |
| 1 440 | 44·1 | 54·07 | 1·838 | 65·8 | 94·60 |
| 1·450 | 44·8 | 55·03 | 1 839 | ... | 95·00 |
| 1 460 | 45·4 | 55·97 | 1 840 | 65·9 | 95·60 |
| 1·470 | 46·1 | 56 90 | 1·8405 | ... | 95·95 |
| 1 480 | 46·8 | 57·83 | 1·8410 | ... | 97·00 |
| 1·490 | 47·4 | 58·74 | 1·8415 | ... | 97·70 |
| 1·500 | 48·1 | 59·70 | 1·8410 | ... | 98·20 |
| 1·510 | 48·7 | 60·65 | 1·8405 | ... | 98·70 |
| 1·520 | 49·4 | 61·59 | 1·8400 | ... | 99·20 |
| 1·530 | 50·0 | 62·53 | 1·8395 | ... | 99·45 |
| 1·540 | 50·6 | 63·43 | 1·8390 | ... | 99·70 |
| 1·550 | 51·2 | 64·26 | 1·8385 | ... | 99·95 |

## Table of Percentages of Caustic Soda (Sodium Hydrate).

| Specific Gravity. | Degree Baumé. | Degree Twaddell. | Percentage NaOH. |
|---|---|---|---|
| 1·007 | 1 | 1·4 | 0·61 |
| 1·014 | 2 | 2·8 | 1·20 |
| 1·022 | 3 | 4·4 | 2·00 |
| 1·029 | 4 | 5·8 | 2·71 |
| 1·036 | 5 | 7·2 | 3·35 |
| 1·045 | 6 | 9·0 | 4·00 |
| 1·052 | 7 | 10·4 | 4·26 |
| 1·060 | 8 | 12·0 | 5·29 |
| 1·067 | 9 | 13·4 | 5·87 |
| 1·075 | 10 | 15·0 | 6·55 |
| 1·083 | 11 | 16·6 | 7·31 |
| 1·091 | 12 | 18·2 | 8·00 |
| 1·100 | 13 | 20·0 | 8·68 |
| 1·108 | 14 | 21·6 | 9·42 |
| 1·116 | 15 | 23·2 | 10·06 |
| 1·125 | 16 | 25·0 | 10·97 |
| 1·134 | 17 | 26·8 | 11·84 |
| 1·142 | 18 | 28·4 | 12·64 |
| 1·152 | 19 | 30·4 | 13·55 |
| 1·162 | 20 | 32·4 | 14·37 |
| 1·171 | 21 | 34·2 | 15·13 |
| 1·180 | 22 | 36·0 | 15·91 |
| 1·190 | 23 | 38·0 | 16·77 |
| 1·200 | 24 | 40·0 | 17·67 |
| 1·210 | 25 | 42·0 | 18·58 |
| 1·220 | 26 | 44·0 | 19·58 |
| 1·231 | 27 | 46·2 | 20·59 |
| 1·241 | 28 | 48·2 | 21·42 |
| 1·252 | 29 | 50·4 | 22·64 |
| 1·263 | 30 | 52·6 | 23·67 |
| 1·274 | 31 | 54·8 | 24·81 |
| 1·285 | 32 | 57·0 | 25·80 |
| 1·297 | 33 | 59·4 | 26·83 |
| 1·308 | 34 | 61·6 | 27·80 |
| 1·320 | 35 | 64·0 | 28·83 |
| 1·332 | 36 | 66·4 | 29·93 |
| 1·345 | 37 | 69·0 | 31·22 |
| 1·357 | 38 | 71·4 | 32·47 |
| 1·370 | 39 | 74·0 | 33·69 |
| 1·383 | 40 | 76·6 | 34·96 |
| 1·397 | 41 | 79·4 | 36·25 |
| 1·410 | 42 | 82·0 | 37·47 |
| 1·424 | 43 | 84·8 | 38·80 |
| 1·438 | 44 | 87·6 | 39·99 |
| 1·453 | 45 | 90·6 | 41·41 |
| 1·468 | 46 | 93·6 | 42·83 |
| 1·483 | 47 | 96·6 | 44·38 |
| 1·498 | 48 | 99·6 | 46·15 |
| 1·514 | 49 | 102·8 | 47·60 |
| 1·530 | 50 | 106·0 | 49·02 |

## Specific Gravity of Solutions of Sodium Carbonate at 15°

(*Lunge*).

| Specific Gravity. | Degrees Baumé. | Degrees Twaddell. | Percentage by Weight. | |
|---|---|---|---|---|
| | | | $Na_2CO_3$. | $Na_2CO_3$ + 10Aq. |
| 1·007 | 1 | 1·4 | 0·67 | 1·807 |
| 1·014 | 2 | 2·8 | 1·33 | 3·587 |
| 1·022 | 3 | 4·4 | 2·09 | 5·637 |
| 1·029 | 4 | 5·8 | 2·76 | 7·444 |
| 1·036 | 5 | 7·2 | 3·43 | 9·251 |
| 1·045 | 6 | 9·0 | 4·29 | 11·570 |
| 1·052 | 7 | 10·4 | 4·94 | 13·323 |
| 1·060 | 8 | 12·0 | 5·71 | 15·400 |
| 1·067 | 9 | 13·4 | 6·37 | 17·180 |
| 1·075 | 10 | 15·0 | 7·12 | 19·203 |
| 1·083 | 11 | 16·6 | 7·88 | 21·252 |
| 1·091 | 12 | 18·2 | 8·62 | 23·248 |
| 1·100 | 13 | 20·0 | 9·43 | 25·432 |
| 1·108 | 14 | 21·6 | 10 19 | 27·482 |
| 1·116 | 15 | 23·2 | 10·95 | 29·532 |
| 1·125 | 16 | 25·0 | 11·81 | 31·851 |
| 1·134 | 17 | 26·8 | 12·61 | 34·009 |
| 1·142 | 18 | 28·4 | 13·16 | 35·493 |
| 1·152 | 19 | 30·4 | 14·24 | 38·405 |

### Table I.—Products of the Distillation of Coal.

| Name. | Formula. | Boiling-point Centigr. |
|---|---|---|
| Hydrogen | HH | ... |
| Marsh gas (hydride of methyl) | $(CH_3)H$ | ... |
| Hydride of hexyl | $(C_6H_{13})H$ | 65 |
| Hydride of octyl | $(C_8H_{17})H$ | 106 |
| Hydride of decyl | $(C_{10}H_{21})H$ | 158 |
| Olefiant gas (ethylene) | $C_2H_4$ | ... |
| Propylene (tritylene) | $C_3H_6$ | ... |
| Caproylene (hexylene) | $C_6H_{12}$ | 55 |
| Œnanthylene (heptylene) | $C_7H_{14}$ | 99 |
| Paraffin | $C_nH_n$ | ... |
| Acetylene | $C_2H_2$ | ... |
| Benzol | $C_6H_6$ | 80·8 |
| Parabenzol | $C_6H_6$ | 97·5 |
| Toluol | $C_7H_8$ | 110 |
| Xylol | $C_8H_{10}$ | 139 |

TABLE I.—*continued.*

| Name. | Formula. | Boiling-point Centigr. |
|---|---|---|
| Cumol | $C_9H_{12}$ | 148·4 |
| Cymol | $C_{10}H_{14}$ | 170·7 |
| Naphthaline | $C_{10}H_8$ | 212 |
| Paranaphthaline (anthracene) | $C_{14}H_{10}$ | ... |
| Chrysen | $C_6H_4$ | ... |
| Pyren | $C_{15}H_4$ | ... |
| Water | $\left.\begin{matrix}H\\H\end{matrix}\right\}O$ | 100 |
| Hydrosulphuric acid | $\left.\begin{matrix}H\\H\end{matrix}\right\}S$ | ... |
| Hydrosulphocyanic acid | $\left.\begin{matrix}H\\(CN)\end{matrix}\right\}S$ | ... |
| Carbonic oxide | $CO$ | ... |
| Carbonic anhydride | $CO_2$ | |
| Bisulphide of carbon | $CS_2$ | 47 |
| Sulphurous anhydride | $SO_2$ | 10 |
| Acetic acid | $\left.\begin{matrix}H\\(C_2H_3O)\end{matrix}\right\}O$ | 120 |
| Carbolic acid (phenol) | $\left.\begin{matrix}H\\(C_6H_5)\end{matrix}\right\}O$ | 188 |
| Cresylic alcohol (cresol) | $\left.\begin{matrix}H\\(C_7H_7)\end{matrix}\right\}O$ | 203 |
| Phlorylic alcohol (phlorol) | $\left.\begin{matrix}H\\(C_8H_9)\end{matrix}\right\}O$ | ... |
| Rosolic acid | $C_{12}H_{12}O_3$ | ... |
| Brunolic acid | ... | ... |
| Ammonia | $\left.\begin{matrix}H\\H\\H\end{matrix}\right\}N$ | 33 |
| Aniline | $\left.\begin{matrix}(C_6H_5)\\H\\H\end{matrix}\right\}N$ | 182 |
| Pyridine | $(C_5H_5)'''N$ | 115 |
| Picoline | $(C_6H_7)'''N$ | 134 |
| Lutidine | $(C_7H_9)'''N$ | 154 |
| Collidine | $(C_8H_{11})'''N$ | 170 |
| Parvoline | $(C_9H_{13})'''N$ | 188 |
| Coridine | $(C_{10}H_{15})'''N$ | 211 |
| Rubidine | $(C_{11}H_{17})'''N$ | 230 |
| Viridine | $(C_{12}H_{19})'''N$ | 251 |
| Leucoline | $(C_9H_7)'''N$ | 235 |
| Lepidine | $(C_{10}H_9)'''N$ | 260 |
| Cryptidine | $(C_{11}H_{11})'''N$ | 256 |
| Pyrrol | $(C_4H_5)'''N$ | 133 |
| Hydrocyanic acid | $HCN$ | 26·5 |

## METRIC SYSTEM OF WEIGHTS AND MEASURES.

THE METRIC SYSTEM has been adopted by Mexico, Brazil, Chile, Peru, etc., and except Russia and Great Britain, where it is permissive, by all European nations. Various names of the preceding systems are, however, frequently used: In Germany, ½ kilogram = 1 pound; in Switzerland, 3-10 of a metre = 1 foot, etc. If the first letters of the prefixes *deka*, *hecto*, *kilo*, *myria*, from the Greek, and *deci*, *centi*, *milli*, from the Latin, are used in preference to our plain English, 10, 100, etc., it is best to employ capital letters for the multiples and small letters for the subdivisions, to avoid ambiguities in abbreviations: 1 dekametre or 10 metres = 1 dm.; 1 decimetre or 1-10 of a metre = 1 dm.

The METRE, unit of length, is nearly the ten-millionth part of a quadrant of a meridian, of the distance between Equator and Pole. The International Standard Metre is, practically, nothing else but a length defined by the distance between two lines on a platinum-iridium bar at 0° Centigrade, deposited at the International Bureau of Weights and Measures, Paris, France.

The LITRE, unit of capacity, is derived from the weight of one kilogram pure water at greatest density, a cube whose edge is one-tenth of a metre and, therefore, the one-thousandth part of a metric ton.

The GRAM, unit of weight, is a cube of pure water at greatest density, whose edge is one-hundredth of a metre, and, therefore, the one-thousandth part of a kilogram, and the one-millionth part of a metric ton.

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The Metric System was legalized in the United States on July 28, 1866, when Congress enacted as follows:

"The tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system, and the tables may lawfully be used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system."

The following are the tables annexed to the above:

### MEASURES OF LENGTH.

| Metric Denominations and Values. | | Equivalents in Denominations in Use. | |
|---|---|---|---|
| Myriametre | 10,000 metres. | 6.2137 | miles. |
| Kilometre | 1,000 metres. | 0.62137 | mile, or 3,280 feet 10 inches. |
| Hectometre | 100 metres. | 328 | feet 1 inch. |
| Dekametre | 10 metres. | 393.7 | inches. |
| Metre | 1 metre. | 39.37 | inches. |
| Decimetre | 1-10 of a metre. | 3.937 | inches. |
| Centimetre | 1-100 of a metre. | 0.3937 | inch. |
| Millimetre | 1-1000 of a metre. | 0.0394 | inch. |

### MEASURES OF SURFACE.

| Metric Denominations and Values. | | Equivalents in Denominations in Use. | |
|---|---|---|---|
| Hectare | 10,000 square metres. | 2.471 | acres. |
| Are | 100 square metres. | 119.6 | square yards. |
| Centare | 1 square metre. | 1,550 | square inches. |

### MEASURES OF CAPACITY.

| Metric Denominations and Values. | | | Equivalents in Denominations in Use. | |
|---|---|---|---|---|
| Names. | Number of Litres. | Cubic Measure. | Dry Measure. | Liquid or Wine Measure. |
| Kilolitre or stere. | 1,000 | 1 cubic metre | 1.308 cubic yards | 264.17 gallons. |
| Hectolitre | 100 | 1-10 of a cubic metre. | 2 bush. and 3.35 pecks | 26.417 gallons. |
| Dekalitre | 10 | 10 cubic decimetres | 9.08 quarts | 2.6417 gallons. |
| Litre | 1 | 1 cubic decimetre | 0.908 quart | 1.0567 quarts. |
| Decilitre | 1-10 | 1-10 of a cubic decimetre. | 6.1022 cubic inches | 0.845 gill. |
| Centilitre | 1-100 | 10 cubic centimetres | 0.6102 cubic inch | 0.338 fluid ounce. |
| Millilitre | 1-1000 | 1 cubic centimetre | 0.061 cubic inch | 0.27 fluid drachm. |

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## METRIC SYSTEM—*Continued.*

### WEIGHTS.

| Metric Denominations and Values. | | | Equivalents in Denominations in Use. |
|---|---|---|---|
| Names. | Number of Grams. | Weight of What Quantity of Water at Maximum Density. | Avoirdupois Weight. |
| Miller or tonneau | 1,000,000 | 1 cubic metre | 2204.6 pounds. |
| Quintal | 100,000 | 1 hectolitre | 220.46 pounds. |
| Myriagram | 10,000 | 10 litres | 22.046 pounds. |
| Kilogram or kilo | 1,000 | 1 litre | 2.2046 pounds. |
| Hectogram | 100 | 1 decilitre | 3.5274 ounces. |
| Dekagram | 10 | 10 cubic centimetres | 0.3527 ounce. |
| Gram | 1 | 1 cubic centimetre | 15.432 grains. |
| Decigram | 1-10 | 1-10 of a cubic centimetre | 1.5432 grains. |
| Centigram | 1-100 | 10 cubic millimetres | 0.1543 grain. |
| Milligram | 1-1000 | 1 cubic millimetre | 0.0154 grain. |

### TABLES FOR THE CONVERSION OF METRIC WEIGHTS AND MEASURES INTO CUSTOMARY UNITED STATES EQUIVALENTS AND THE REVERSE.

From the legal equivalents are deduced the following tables for converting United States weights and measures:

**METRIC TO CUSTOMARY. — CUSTOMARY TO METRIC.**

#### LINEAR MEASURE.

| *Metres—Ins.* | *Metres—Feet.* | *Metres—Yards.* | *Kilometres—Miles.* | *Ins.—Centimetres* | *Feet—Metres.* | *Yards—Metres.* | *Miles—Kilometres.* |
|---|---|---|---|---|---|---|---|
| 1— 39.37 | 1— 3.28083 | 1—1.093611 | 1—0.62137 | 1— 2.54 | 1—0.304801 | 1—0.914402 | 1— 1.60935 |
| 2— 78.74 | 2— 6.56167 | 2—2.187222 | 2—1.24274 | 2— 5.08 | 2—0.609601 | 2—1.828804 | 2— 3.21869 |
| 3—118.11 | 3— 9.84250 | 3—3.280833 | 3—1.86411 | 3— 7.62 | 3—0.914402 | 3—2.743205 | 3— 4.82804 |
| 4—157.48 | 4—13.12333 | 4—4.374444 | 4—2.48548 | 4—10.16 | 4—1.219202 | 4—3.657607 | 4— 6.43739 |
| 5—196.85 | 5—16.40417 | 5—5.468056 | 5—3.10685 | 5—12.70 | 5—1.524003 | 5—4.572009 | 5— 8.04674 |
| 6—236.22 | 6—19.68500 | 6—6.561667 | 6—3.72822 | 6—15.24 | 6—1.828804 | 6—5.486411 | 6— 9.65608 |
| 7—275.59 | 7—22.96583 | 7—7.655278 | 7—4.34959 | 7—17.78 | 7—2.133604 | 7—6.400813 | 7—11.26543 |
| 8—314.96 | 8—26.24667 | 8—8.748989 | 8—4.97096 | 8—20.32 | 8—2.438405 | 8—7.315215 | 8—12.87478 |
| 9—354.33 | 9—29.52750 | 9—9.842500 | 9—5.59233 | 9—22.86 | 9—2.743205 | 9—8.229616 | 9—14.48412 |

#### SQUARE MEASURE. — CUBIC MEASURE. — SQUARE MEASURE.

| *Square Centimet's—Square Inches.* | *Square Metres—Square Feet.* | *Square Metres—Square Yards.* | *Cubic Metres—Cubic Feet.* | *Cubic Feet—Cubic Metres.* | *Square Inches—Square Centimet's* | *Square Feet—Square Metres.* | *Square Yards—Square Metres.* |
|---|---|---|---|---|---|---|---|
| 1—0.155 | 1—10.764 | 1— 1.196 | 1— 35.314 | 1—0.02832 | 1— 6.452 | 1—0.09290 | 1—0.836 |
| 2—0.310 | 2—21.528 | 2— 2.392 | 2— 70.629 | 2—0.05663 | 2—12.903 | 2—0.18581 | 2—1.672 |
| 3—0.465 | 3—32.292 | 3— 3.588 | 3—105.943 | 3—0.08495 | 3—19.354 | 3—0.27871 | 3—2.508 |
| 4—0.620 | 4—43.055 | 4— 4.784 | 4—141.258 | 4—0.11327 | 4—25.806 | 4—0.37161 | 4—3.344 |
| 5—0.775 | 5—53.819 | 5— 5.980 | 5—176.572 | 5—0.14159 | 5—32.257 | 5—0.46452 | 5—4.181 |
| 6—0.930 | 6—64.583 | 6— 7.176 | 6—211.887 | 6—0.16990 | 6—38.709 | 6—0.55742 | 6—5.017 |
| 7—1.085 | 7—75.347 | 7— 8.372 | 7—247.201 | 7—0.19822 | 7—45.160 | 7—0.65032 | 7—5.853 |
| 8—1.240 | 8—86.111 | 8— 9.568 | 8—282.516 | 8—0.22654 | 8—51.612 | 8—0.74323 | 8—6.689 |
| 9—1.395 | 9—96.874 | 9—10.764 | 9—317.830 | 9—0.25485 | 9—58.063 | 9—0.83613 | 9—7.525 |

#### LIQUID MEASURE. — DRY MEASURE. — LIQUID MEASURE.

| *Centilitres—Fluid Ounces.* | *Litres—Quarts.* | *Litres—Gallons.* | *Hectolitres—Bushels.* | *Bushels—Hectolitres* | *Fluid Ounces—Centilitres* | *Quarts—Litres.* | *Gallons—Litres.* |
|---|---|---|---|---|---|---|---|
| 1—0.338 | 1—1.0567 | 1—0.26417 | 1— 2.8377 | 1—0.35239 | 1— 2.957 | 1—0.94636 | 1— 3.78543 |
| 2—0.676 | 2—2.1134 | 2—0.52834 | 2— 5.6754 | 2—0.70479 | 2— 5.914 | 2—1.89272 | 2— 7.57087 |
| 3—1.014 | 3—3.1700 | 3—0.79251 | 3— 8.5132 | 3—1.05718 | 3— 8.872 | 3—2.83908 | 3—11.35630 |
| 4—1.352 | 4—4.2267 | 4—1.05668 | 4—11.3509 | 4—1.40957 | 4—11.829 | 4—3.78544 | 4—15.14174 |
| 5—1.691 | 5—5.2834 | 5—1.32085 | 5—14.1887 | 5—1.76196 | 5—14.786 | 5—4.73180 | 5—18.92717 |
| 6—2.028 | 6—6.3401 | 6—1.58502 | 6—17.0264 | 6—2.11436 | 6—17.744 | 6—5.67816 | 6—22.71261 |
| 7—2.367 | 7—7.3968 | 7—1.84919 | 7—19.8642 | 7—2.46675 | 7—20.701 | 7—6.62452 | 7—26.49804 |
| 8—2.705 | 8—8.4534 | 8—2.11336 | 8—22.7019 | 8—2.81914 | 8—23.659 | 8—7.57088 | 8—30.28348 |
| 9—3.043 | 9—9.5101 | 9—2.37753 | 9—25.5396 | 9—3.17154 | 9—26.616 | 9—8.51724 | 9—34.06891 |

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### WEIGHT (AVOIRDUPOIS).

| Centigrams = Grains. | Kilograms = Ounces Av'd'ps. | Kilograms = Pounds Av'd'ps. | Metric Tons = Long Tons. | Grains = Centigrams | Ounces Av'd'ps = Grams | Pounds Av'd'ps = Kilograms. | Long Tons = Metric Tons. |
|---|---|---|---|---|---|---|---|
| 1=0.1543 | 1= 35.274 | 1= 2.20462 | 1=0.9842 | 1= 6 4799 | 1= 28.3495 | 1=0.45359 | 1=1.0161 |
| 2=0.3086 | 2= 70.548 | 2= 4.40924 | 2=1.9684 | 2=12.9598 | 2= 56 6991 | 2=0.90719 | 2=2.0321 |
| 3=0.4630 | 3=105.822 | 3= 6.61386 | 3=2.9526 | 3=19.4397 | 3= 85.0486 | 3=1.36078 | 3=3.0482 |
| 4=0.6173 | 4=141.096 | 4= 8.81849 | 4=3.9368 | 4=25.9196 | 4=113.3981 | 4=1.81437 | 4=4.0642 |
| 5=0.7716 | 5=176.370 | 5=11.02311 | 5=4.9210 | 5=32.3995 | 5=141.7476 | 5=2 26796 | 5=5.0803 |
| 6=0.9259 | 6=211.644 | 6=13.22773 | 6=5.9052 | 6=38 8793 | 6=170.0972 | 6=2.72156 | 6=6.0963 |
| 7=1.0803 | 7=246.918 | 7=15.43235 | 7=6.8894 | 7=45.3592 | 7=198.4467 | 7=3.17515 | 7=7 1124 |
| 8=1.2346 | 8=282.192 | 8=17.63697 | 8=7.8736 | 8=51.8391 | 8=226.7962 | 8=3.62874 | 8=8.1284 |
| 9=1.3889 | 9=317.466 | 9=19.84159 | 9=8.8578 | 9=58.3190 | 9=255.1457 | 9=4.08233 | 9=9.1445 |

## THE METRIC SYSTEM SIMPLIFIED.

The following tables of the metric system of weights and measures have been simplified as much as possible for THE WORLD ALMANAC by omitting such denominations as are not in practical, everyday use in the countries where the system is used exclusively.

### TABLES OF THE SYSTEM.

**Length.**—The denominations in practical use are millimetres (mm.), centimetres (cm.), metres (m.), and kilometres (km.).

10 mm. = 1 cm.; 100 cm. = 1 m.; 1,000 m. = 1 km. NOTE.—A decimetre is 10 cm.

**Weight.**—The denominations in use are grams (g.), kilos* (kg.), and tons (metric tons).

1,000 g. = 1 kg.; 1,000 kg. = 1 metric ton.

**Capacity.**—The denominations in use are cubic centimetres (c.c.) and litres (l.).

1,000 c.c. = 1 l. NOTE.—A hectolitre is 100 l. (seldom used)

Relation of capacity and weight to length. A cubic decimetre is a litre, and a litre of water weighs a kilo.

### APPROXIMATE EQUIVALENTS.

A metre is about a yard; a kilo is about 2 pounds; a litre is about a quart; a centimetre is about ⅖ inch; a metric ton is about same as a ton; a kilometre is about ⅝ mile; a cubic centimetre is about a thimbleful; a nickel weighs about 5 grams.

### PRECISE EQUIVALENTS.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 acre = | .40 | hectare | 4 047 | 1 mile = | 1.6 | kilometres | 1.609 |
| 1 bushel = | 35 | litres | 35.24 | 1 millimetre = | .039 | inch | .0394 |
| 1 centimetre = | .39 | inch | .3937 | 1 ounce (av'd) = | 28 | grams | 28.35 |
| 1 cubic centimetre = | .061 | cubic inch | .0610 | 1 ounce (Troy) = | 31 | grams | 31.10 |
| 1 cubic foot = | .028 | cubic metre | .0283 | 1 peck = | 8.8 | litres | 8.809 |
| 1 cubic inch = | 16 | cubic cent.† | 16.39 | 1 pint = | .47 | litre | .4732 |
| 1 cubic metre = | 35 | cubic feet | 35.31 | 1 pound = | .45 | kilo | .4536 |
| 1 cubic metre = | 1.3 | cubic yards | 1.308 | 1 quart (dry) = | 1.1 | litres | 1.101 |
| 1 cubic yard = | .76 | cubic metre | .7645 | 1 quart (liquid) = | .95 | litre | .9464 |
| 1 foot = | 30 | centimetres | 30.48 | 1 sq. centimetre = | .15 | sq. inch | .1550 |
| 1 gallon = | 3.8 | litres | 3.785 | 1 sq. foot = | .093 | sq. metre | .0929 |
| 1 grain = | .065 | gram | .0648 | 1 sq. inch = | 6.5 | sq. c'timetr's. | 6.452 |
| 1 gram = | 15 | grains | 15.43 | 1 sq. metre = | 1.2 | sq. yards | 1.196 |
| 1 hectare = | 2.5 | acres | 2.471 | 1 sq. metre = | 11 | sq. feet | 10.76 |
| 1 inch = | 25 | millimetres | 25.40 | 1 sq. yard = | .84 | sq. metre | .8361 |
| 1 kilo = | 2.2 | pounds | 2.205 | 1 ton (2,000 lbs.) = | .91 | metric ton | .9072 |
| 1 kilometre = | .62 | mile | .6214 | 1 ton (2,240 lbs.) = | 1 | metric ton | 1 017 |
| 1 litre = | .91 | quart (dry) | .9081 | 1 ton (metric) = | 1.1 | ton (2,000 lbs.) | 1.102 |
| 1 litre = | 1.1 | quarts (liq'd) | 1.057 | 1 ton (metric) = | .98 | ton (2,240 lbs.) | .9842 |
| 1 metre = | 3.3 | feet | 3.281 | 1 yard = | .91 | metre | .9144 |

*Contraction for kilogram. †Centimetres.

## MEASURES AND WEIGHTS OF GREAT BRITAIN.

THE measures of length and the weights are nearly practically, the same as those in use in the United States. The English ton is 2,240 lbs. avoirdupois, the same as the long ton, or shipping ton of the United States. The English hundredweight is 112 lbs avoirdupois the same as the long hundredweight of the United States. The English stone is usually equal to one eighth hundredweight of 112 lbs., or 14 lbs. avoirdupois. The metre has been legalized at 39 37079 inches, but the length of 39.370432 inches, as adopted by France, Germany, Belgium, and Russia is frequently used.

The Imperial gallon, the basis of the system of capacity, involves an error of about 1 part in 1.836; 10 lbs. of water = 277.123 cubic inches. (A late authority gives the weight of the Imperial gallon as 10.017 pounds and of the United States gallon as 8.345 pounds.)

The English statute mile is 1,760 yards or 5,280 feet. The following are measures of capacity:

| NAMES. | Pounds of Water. | Cubic Inches. | Litres. | United States Equivalents. |
|---|---|---|---|---|
| 4 gills = 1 pint | 1.25 | 34.66 | 0.56793 | 1.20032 liquid pints. |
| 2 pints = 1 quart | 2.5 | 69.32 | 1 13586 | 1.20032 " quarts. |
| 2 quarts = 1 pottle | 5 | 138.64 | 2.27173 | 2.40064 " " |
| 2 pottles = 1 gallon | 10 | 277.27 | 4.54346 | 1 20032 " gallons. |
| 2 gallons = 1 peck | 20 } Dry measure | 554.55 | 9.08692 | 1 03152 dry pecks. |
| 4 pecks = 1 bushel | 80 | 2218.19 | 36 34766 | 1 03152 " bushels. |
| 4 bushels = 1 coomb | 320 | 8872.77 | 145.39062 | 4 12606 " " |
| 2 coombs = 1 quarter | 640 | 17745.54 | 290.7813 | 8.2521 " " |

A cubic foot of pure gold weighs 1,210 pounds; pure silver, 655 pounds. cast iron, 450 pounds; copper, 550 pounds; lead 710 pounds; pure platinum, 1,220 pounds; tin, 456 pounds; aluminum, 163 pounds

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## KNOTS AND MILES.

**The Statute Mile** is 5,280 feet.

**The British Admiralty Knot or Nautical Mile** is 6,080 feet.

**The Statute Knot** is 6,082.66 feet, and is generally considered the standard. The number of feet in a statute knot is arrived at thus: The circumference of the earth is divided into 360 degrees, each degree containing 60 knots or (360x60), 21,600 knots to the circumference. 21,600 divided into 131,385,456—the number of feet in the earth's circumference—gives 6,082.66 feet—the length of a standard mile.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 knot | = 1.151 miles | 4 knots | = 4.606 miles | 20 knots | = 23.030 miles | 600 feet | = 1 cable |
| 2 knots | = 2.303 miles | 5 knots | = 5.757 miles | 25 knots | = 28.787 miles | 10 cables | = 1 knot |
| 3 knots | = 3.454 miles | 10 knots | = 11.515 miles | 6 feet | = 1 fathom | | |

## ANCIENT GREEK AND ROMAN WEIGHTS AND MEASURES.

WITH AMERICAN EQUIVALENTS.

WEIGHTS.

The Roman libra or pound = 10 oz. 18 pwt. 13 5-7 gr., Troy.
The Attica mina or pound = 11 oz. 7 pwt. 16 2-7 gr., Troy.
The Attica talent (60 minæ) = 56 lbs. 11 oz. 0 pwt. 17 1-7 gr., Troy.

DRY MEASURE.

The Roman modus = 1 pk. 2-9 pint.
The Attic chœnix = nearly 1⅛ pints.
The Attic medimnus = 4 pk. 6 1-10 pints.

LIQUID MEASURE.

The cotyle = a little over ½ pint.
The cyathus = a little over 1⅛ pints.
The chus = a little over 6⅞ pints.

LONG MEASURE.

The Roman foot = 11 3-5 inches.
The Roman cubit = 1 ft. 5⅘ inches.
The Roman pace = 4 ft. 10 inches.
The Roman furlong = 604 ft. 10 inches.
The Roman mile = 4,835 feet.
The Grecian cubit = 1 ft. 6⅛ inches.
The Grecian furlong = 504 ft. 4 1-5 inches.
The Grecian mile = 4,030 ft.

MONEY.

The quadrans = 1 1-10 mills.
The as = 1 3-10 mills.
The sestertius = 3.58 + cents.
The sestertium (1,000 sestertii) = $35.80+.
The denarius = 14.35 + cents.
The Attic obolus = 2.39 + cents.
The drachma = 14.35 + cents.*
The mina (100 drachmæ) = $14.35+.
The talent (60 minæ) = $861.00+.
The Greek stater = aureus (same as the Roman †) = $3.58,79.
The stater = daricus = $7.16,66.

*The modern drachma equals 19.3 cents. † Did not remain, at all periods, at this value, but this is the value indicated by Tacitus.

## BIBLICAL WEIGHTS REDUCED TO TROY WEIGHT.

| | Lbs. | Oz. | Pwt. | Gr. |
|---|---|---|---|---|
| The Gerah, one-twentieth of a Shekel | 0 | 0 | 0 | 12 |
| The Bekah, half a Shekel | 0 | 0 | 5 | 0 |
| The Shekel | 0 | 0 | 10 | 0 |
| The Maneh, 60 Shekels | 2 | 6 | 0 | 0 |
| The Talent, 50 manehs, or 3,000 Shekels | 125 | 0 | 0 | 0 |

## DOMESTIC WEIGHTS AND MEASURES.

**Apothecaries' Weight:** 20 grains = 1 scruple; 3 scruples = 1 dram; 8 drams = 1 ounce; 12 ounces = 1 pound.

**Avoirdupois Weight** (short ton): 27 11-32 grains = 1 dram; 16 drams = 1 ounce; 16 ounces = 1 pound; 25 pounds = 1 quarter; 4 quarters = 1 cwt.; 20 cwt. = 1 ton

**Avoirdupois Weight** (long ton): 27 11-32 grains = 1 dram; 16 drams = 1 ounce; 16 ounces = 1 pound; 112 pounds = 1 cwt.; 20 cwt = 1 ton.

**Troy Weight:** 24 grains = 1 pennyweight; 20 pennyweights = 1 ounce; 12 ounces = 1 pound.

**Circular Measure:** 60 seconds = 1 minute; 60 minutes = 1 degree; 30 degrees = 1 sign; 12 signs = 1 circle or circumference.

**Cubic Measure:** 1,728 cubic inches = 1 cubic foot; 27 cubic feet = 1 cubic yard.

**Dry Measure:** 2 pints = 1 quart; 8 quarts = 1 peck; 4 pecks = 1 bushel.

**Liquid Measure:** 4 gills = 1 pint; 2 pints = 1 quart; 4 quarts = 1 gallon; 31½ gallons = 1 barrel; 2 barrels = 1 hogshead.

**Long Measure:** 12 inches = 1 foot; 3 feet = 1 yard; 5½ yards = 1 rod or pole; 40 rods = 1 furlong; 8 furlongs = 1 statute mile (1,760 yards or 5,280 feet); 3 miles = 1 league.

**Mariners' Measure:** 6 feet = 1 fathom; 120 fathoms = 1 cable length; 7⅓ cable lengths = 1 mile; 5,280 feet = 1 statute mile; 6,085 feet = 1 nautical mile.

**Paper Measure:** 24 sheets = 1 quire; 20 quires = 1 ream (480 sheets); 2 reams = 1 bundle; 5 bundles = 1 bale.

**Square Measure:** 144 square inches = 1 square foot; 9 square feet = 1 square yard; 30¼ square yards = 1 square rod or perch; 40 square rods = 1 rood; 4 roods = 1 acre; 640 acres = 1 square mile; 36 square miles (6 miles square) = 1 township.

**Time Measure:** 60 seconds = 1 minute; 60 minutes = 1 hour; 24 hours = 1 day; 7 days = 1 week; 365 days = 1 year; 366 days = 1 leap year.

## MEDICAL SIGNS AND ABBREVIATIONS.

℞ (Lat. Recipe), take; āā, of each; ℔, pound; ℥, ounce; ʒ, drachm; ℈, scruple; ♏, minim, or drop; O or o, pint; f℥, fluid ounce; fʒ, fluid drachm; as, ℥ss, half an ounce; ℥i, one ounce; ℥iss, one ounce and a half; ℥ij, two ounces; gr., grain; Q. S., as much as sufficient; Ft. Mist., let a mixture be made; Ft. Haust., let a draught be made; Ad., add to; Ad lib., at pleasure; Aq., water; M., mix; Mac., macerate; Pulv., powder; Pil., pill; Solv., dissolve; St., let it stand; Sum., to be taken; D., dose; Dil., dilute; Filt., filter; Lot., a wash; Garg., a gargle; Hor. Decub., at bed time; Inject., injection; Gtt., drops; ss, one-half; Ess., essence.

## WEIGHTS AND MEASURES OF THE PHILIPPINES.

| | | | |
|---|---|---|---|
| 1 pulgada (12 lineas) | = .927 inch. | 1 libra (16 onzo) | = 1.0144 lb av. |
| 1 pie | = 11.125 inches. | 1 arroba | = 25.360 lb. av. |
| 1 vara | = 33.375 inches. | 1 catty (16 tael) | = 1.394 lb av. |
| 1 gantah | = .8796 gallon. | 1 pecul (100 catty) | = 139.482 lb. av. |
| 1 caban | = 21.991 gallons. | | |

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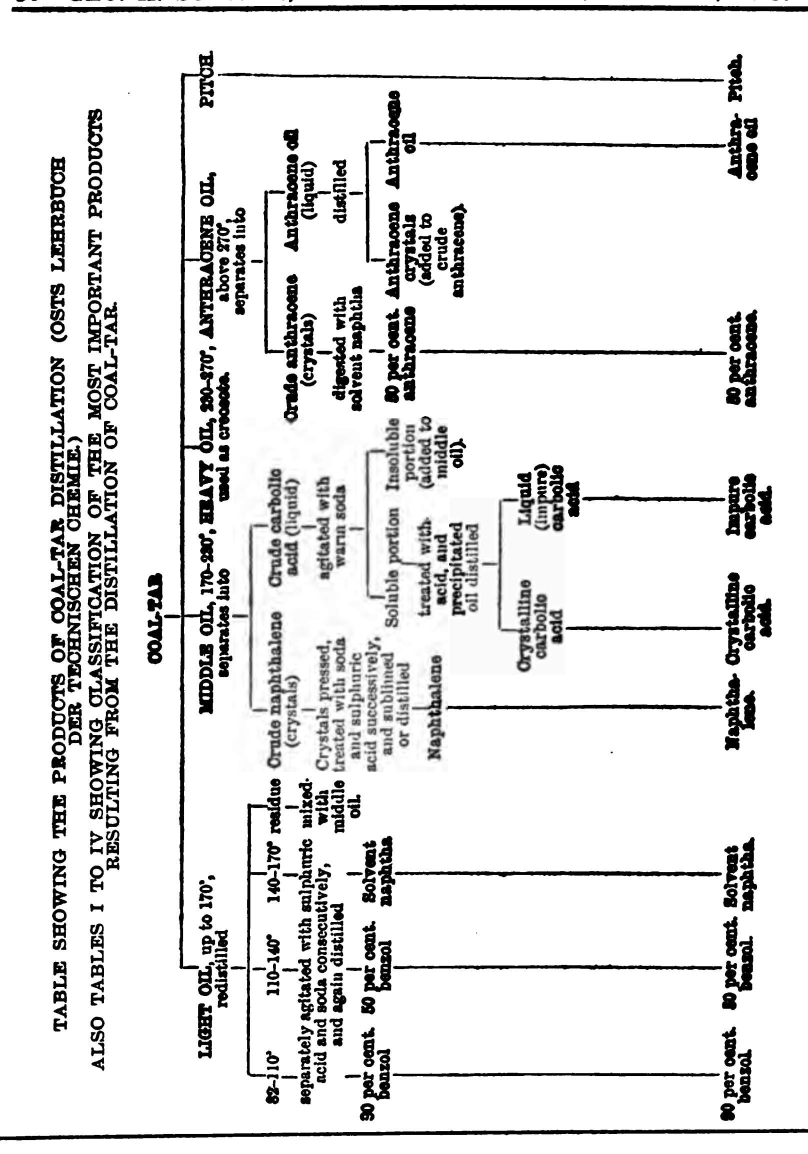



TABLE SHOWING THE PRODUCTS OF COAL-TAR DISTILLATION (OSTS LEHRBUCH DER TECHNISCHEN CHEMIE.)
ALSO TABLES I TO IV SHOWING CLASSIFICATION OF THE MOST IMPORTANT PRODUCTS RESULTING FROM THE DISTILLATION OF COAL-TAR.

## I. *Hydrocarbons*

| | Formula. | Melting Point. | Boiling Point. |
|---|---|---|---|
| **Hydrocarbons of the acetylene series** | $C_nH_{2n-2}$ | Fluid | 20° |
| **Hydrocarbons of the ethylene series** . | $C_nH_{2n}$ | ... | ... |
| **Hydrocarbons of the methane series** . | $C_nH_{2n+2}$ | ... | ... |
| **Cyclopentadiene** . . . . . | $C_5H_6$ | Fluid | 41° |
| **Benzene** . . . . . . . . | $C_6H_6$ | 6° | 81° |
| **Toluene** . . . . . . . . | $C_7H_8$ | Fluid | 111° |
| ***o*-Xylene** . . . . . . . . | $C_8H_{10}$ | " | 142° |
| ***m*-Xylene** . . . . . . . . | $C_8H_{10}$ | " | 139° |
| ***p*-Xylene** . . . . . . . . | $C_8H_{10}$ | 15° | 138° |

## I. *Hydrocarbons* (continued)

| | Formula. | Melting Point. | Boiling Point. |
|---|---|---|---|
| **Styrene** | $C_8H_8$ | Fluid | 146° |
| **Indene** | $C_9H_8$ | ,, | 176°—182° |
| **Mesitylene** | $C_9H_{12}$ | ,, | 163° |
| **Pseudocumene** | $C_9H_{12}$ | ,, | 169° |
| **Naphthalene** | $C_{10}H_8$ | 80° | 218° |
| **Methylnaphthalene** | $C_{11}H_{10}$ | α Fluid ; β 33° | 242° |
| **Dimethylnaphthalene** | $C_{12}H_{12}$ | Fluid | 264° |
| **Diphenyl** | $C_{12}H_{10}$ | 71° | 254° |
| **Acenaphthene** | $C_{12}H_{10}$ | 95° | 277° |
| **Fluorene** | $C_{13}H_{10}$ | 113° | 295° |
| **Phenanthrene** | $C_{14}H_{10}$ | 100° | 340° |
| **Fluoranthrene** | $C_{15}H_{10}$ | 109° | Above 360° |
| **Anthracene** | $C_{14}H_{10}$ | 213° | ,, |
| **Methylanthracene** | $C_{15}H_{12}$ | 210° | ,, |
| **Pyrene** | $C_{16}H_{10}$ | 149° | ,, |
| **Chrysene** | $C_{18}H_{12}$ | 250° | ,, |
| **Picene or Parachrysene** | $C_{22}H_{14}$ | 239° | 520° |

## II. *Other Neutral Bodies*

| | Formula. | Melting Point. | Boiling Point. |
|---|---|---|---|
| **Carbon disulphide** | $CS_2$ | Fluid | 47° |
| **Ethyl alcohol** | $C_2H_5 \cdot OH$ | ,, | 78° |
| **Acetonitrile** | $C_2H_3N$ | ,, | 82° |
| **Thiophene** | $C_4H_4S$ | ,, | 84° |
| **Thiotolene** | $C_5H_6S$ | ,, | 113° |
| **Thioxene** | $C_6H_8S$ | ,, | 137° |
| **Benzonitrile** | $C_7H_5N$ | ,, | 191° |
| **Phenythiocarbimide** | $C_7H_5NS$ | ,, | 220° |
| **Carbazole** | $C_{12}H_9N$ | 238° | 355° |
| **Phenylnaphthylcarbazole** | $C_{16}H_{11}N$ | 330° | Above 440° |
| **Coumarone** | $C_8H_6O$ | Fluid | 170° |
| **Diphenylene oxide** | $C_{12}H_8O$ | 81° | 288° |

## III. *Bases*

| | Formula. | Melting Point. | Boiling Point. |
|---|---|---|---|
| **Pyrrol** | $C_4H_5N$ | Fluid | 126° |
| **Pyridine** | $C_5H_5N$ | ,, | 116° |
| **Picoline** (α, β, and γ) | $C_6H_7N$ | ,, | 134°—144° |
| **Lutidine** (4 isomers) | $C_7H_9N$ | ,, | 142°—157° |
| **Collidine** | $C_8H_{11}N$ | ,, | 179° |
| **Aniline** | $C_6H_7N$ | ,, | 182° |
| **Quinoline** | $C_9H_7N$ | ,, | 239° |
| **Quinaldine** | $C_{10}H_9N$ | ,, | 243° |
| **Acridine** | $C_{13}H_9N$ | 107° | Above 360° |

## IV. *Phenols*

| | Formula. | Melting Point. | Boiling Point. |
|---|---|---|---|
| **Phenol** | $C_6H_6O$ | 42° | 188° |
| *o*-**Cresol** | $C_7H_8O$ | 31° | 188° |
| *p*-**Cresol** | $C_7H_8O$ | 36° | 198° |
| *m*-**Cresol** | $C_7H_8O$ | 4° | 201° |
| α-**Naphthol** | $C_{10}H_8O$ | 94° | 280° |
| β-**Naphthol** | $C_{10}H_8O$ | 123° | 286° |
| **Xylenols and other high boiling phenols** | ... | ... | ... |

*By Act of Parliament* (27 *and* 28 *Vict. cap.* 117, 29*th July*, 1864) *the use of the Metrical System of Weights and Measures is rendered legal. The weight of the Kilogram is settled by this Act to be equal to* 15432·3488 *English Grains.*

COMPARISON OF THE METRICAL WITH THE COMMON MEASURES. BY DR. WARREN DE LA RUE.

MEASURES OF LENGTH.

| | In English Inches. | In English Feet =12 Inches. | In English Yards =3 Feet. | In English Fathoms =6 Feet. | In English Miles =1,760 Yards. |
|---|---|---|---|---|---|
| Millimeter | 0·03937 | 0·0032809 | 0·0010936 | 0·0005468 | 0·0000006 |
| Centimeter | 0·39371 | 0·0328090 | 0·0109363 | 0·0054682 | 0·0000062 |
| Decimeter | 3·93708 | 0·3280899 | 0·1093633 | 0·0546816 | 0·0000621 |
| Meter | 39·37079 | 3·2808992 | 1·0936331 | 0·5468165 | 0·0006214 |
| Decameter | 393·70790 | 32·8089920 | 10·9363310 | 5·4681655 | 0·0062138 |
| Hectometer | 3937·07900 | 328·0899200 | 109·3633100 | 54·6816550 | 0·0621382 |
| Kilometer | 39370·79000 | 3280·8992000 | 1093·6331000 | 546·8165500 | 0·6213824 |
| Myriameter | 393707·90000 | 32808·9920000 | 10936·3310000 | 5468·1655000 | 6·2138244 |

1 Inch = 2·539954 Centimeters.
1 Foot = 3·0479449 Decimeters.
1 Yard = 0·91438348 Meter.
1 Mile = 1·6093149 Milometer.

MEASURES OF SURFACE.

| | In English Square Feet. | In English Square Yards=9 Square Feet. | In English Poles =272·25 Square Feet. | In English Roods =10,890 Square Feet. | In English Acres =43,560 Square Feet. |
|---|---|---|---|---|---|
| Centiare or square meter | 10·7642993 | 1·1960333 | 0·0395383 | 0·000988457 | 0·0002471143 |
| Are or 100 square meters | 1076·4299342 | 119·6033260 | 3·9538290 | 0·098845724 | 0·0247114310 |
| Hectare or 10,000 square meters | 107642·9934183 | 11960·3326020 | 395·3828959 | 9·884572398 | 2·4711430996 |

1 Square Inch = 6·4513669 Square Centimeters.
1 Square Foot = 9·2899683 Square Decimeters.
1 Square Yard = 0·83609715 Square Meter or Centiare.
1 Acre = 0·404671021 Hectare.

## MEASURES OF CAPACITY.

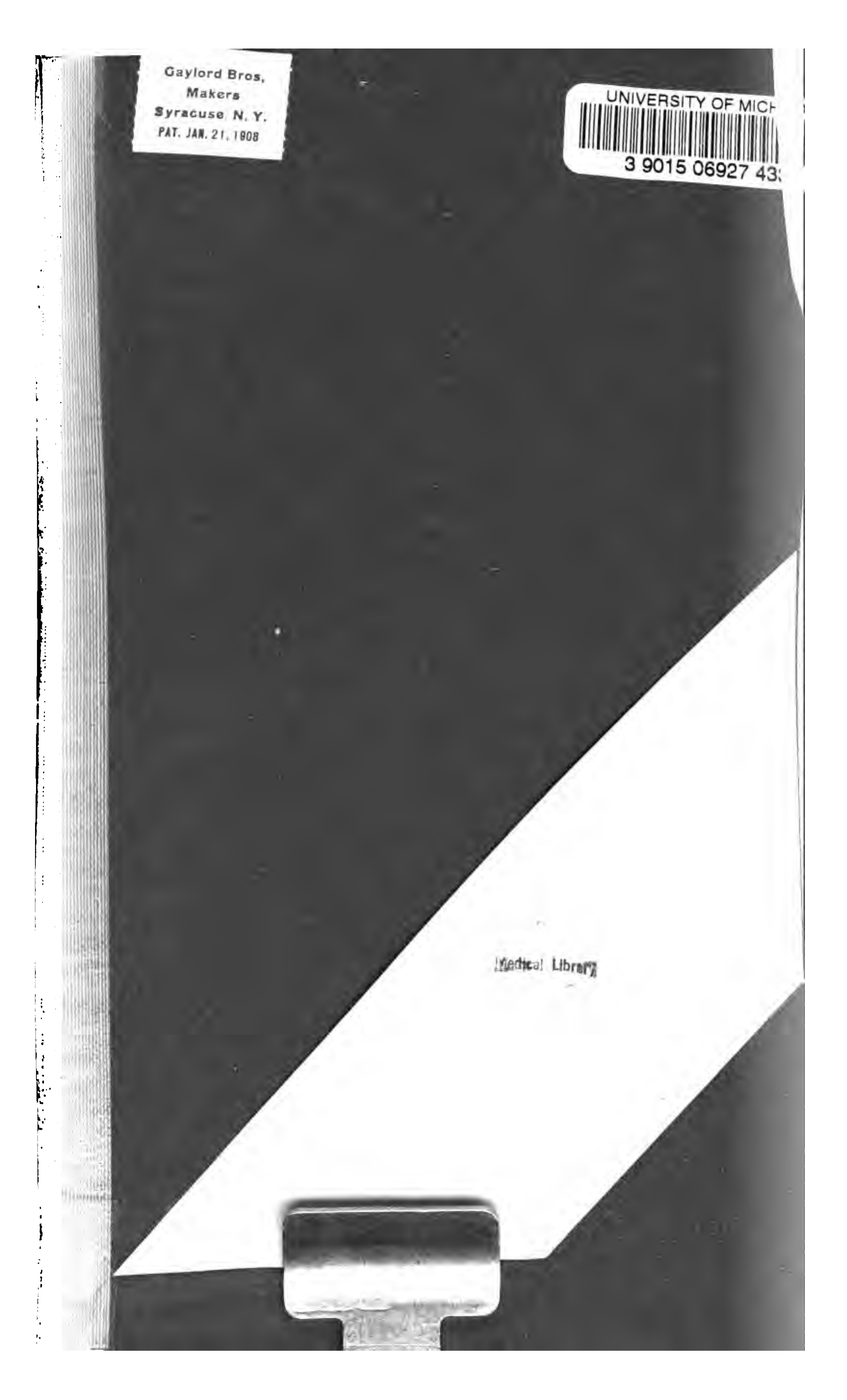
| | In Cubic Inches. | In Cubic Feet =1,728 Cubic Inches. | In Pints=34·65923 Cubic Inches. | In Gallons=8 Pints =277·27384 Cubic Inches. | In Bushels=8 Gallons =2218·19075 Cubic Inches. |
|---|---|---|---|---|---|
| Milliliter, or cubic centimeter | 0·061027 | 0·0000353 | 0·001761 | 0·00022010 | 0·000027512 |
| Centiliter, or 10 cubic centimeters | 0·610271 | 0·0003532 | 0·017608 | 0·00220097 | 0·000275121 |
| Deciliter, or 100 cubic centimeters | 6·102705 | 0·0035317 | 0·176077 | 0·02200967 | 0·002751208 |
| Liter, or cubic decimeter | 61·027052 | 0·0353166 | 1·760773 | 0·22009668 | 0·027512085 |
| Decaliter, or centistere | 610·270515 | 0·3531658 | 17·607734 | 2·20096677 | 0·275120846 |
| Hectoliter, or decistere | 6102·705152 | 3·5316581 | 176·077341 | 22·00966767 | 2·751208459 |
| Kiloliter, or stere, or cubic meter | 61027·051519 | 35·3165807 | 1760·773414 | 220·09667675 | 27·512084594 |
| Myrialiter, or decastere | 610270·515194 | 353·1658074 | 17607·734140 | 2200·96676750 | 275·120845937 |

1 Cubic Inch = 16·3861759 Cubic Centimeters. 1 Cubic Foot = 28·3153119 Cubic Decimeters.
1 Gallon = 4·543457969 Liters.

## MEASURES OF WEIGHT.

| | In English Grains. | In Troy Ounces =480 Grains. | In Avoirdupois Lbs. =7,000 Grains. | In Cwts.=112 Lbs. =734,000 Grains. | Tons=20 Cwts. =15,620,000 Grains. |
|---|---|---|---|---|---|
| Milligram | 0·015432 | 0·000032 | 0·0000022 | 0·00000002 | 0·000000001 |
| Centigram | 0·154323 | 0·000322 | 0·0000220 | 0·00000020 | 0·000000010 |
| Decigram | 1·543235 | 0·003215 | 0·0002205 | 0·00000197 | 0·000000098 |
| Gram | 15·432349 | 0·032151 | 0·0022046 | 0·00001968 | 0·000000984 |
| Decagram | 154·323488 | 0·321507 | 0·0220462 | 0·00019684 | 0·000009842 |
| Hectogram | 1543·234880 | 3·215073 | 0·2204621 | 0·00196841 | 0·000098421 |
| Kilogram | 15432·348800 | 32·150727 | 2·2046213 | 0·01968412 | 0·000984206 |
| Myriagram | 154323·488000 | 321·507267 | 22·0462126 | 0·19684118 | 0·009842059 |

1 Grain = 0·064798950 Gram. 1 Lb. Avd. = 0·45359265 Kilog.
1 Troy oz. = 31·103496 Grams. 1 Cwt. = 50·80237689 Kilog.


Gaylord Bros,
Makers
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